Special Report: 1986 MRS Fall Meeting

2,500 Scientists Participate in Symposia, Exhibit, Short Courses, Forum

The cold northern winter never puts a damper on the enthusiasm of attendees at the MRS Fall Meeting held annually in Boston, Massachusetts, and 1986 was no exception. Approximately 2,500 materials scientists from around the world participated in this meeting, held the week of December 1-5. The 22 technical symposia overflowed from the Marriott to the Westin Hotel, where Tuesday and Thursday evenings, lively poster sessions were also held. Two evening oral sessions were also held to accommodate the overwhelming response to the symposium on Interfaces, Superlattices, and Thin Films. The equipment exhibit, featuring 120 displays, offered for the first time full equipment displays, as the event outgrew the tabletop format.

The Monday evening Plenary Address by Congressman George E. Brown (Democract, California) called upon the materials community to get involved in setting the direction for national materials policies. Perhaps his words inspired the crowd, for at the end of the week, the Society's first Forum, addressing topics for consideration by the national Materials Science and Engineering Study, drew a standing-room-only crowd. A roster of 22 short courses ran throughout the week, enabling attendees to maximize their participation in symposia and courses on the same topics. Wednesday evening, Prof. Minko Balkanski was honored as the 1986 recipient of the Von Hippel Award, 14 graduate students were recognized for outstanding research and promise, a new Student Chapter at the University of Wisconsin, Madison, received its Certificate of Charter, and the new Delaware Valley Section also received its Charter.

The popular lunchtime symposium on Frontiers in Materials Research featured a special "History of Materials Research" session on Monday, with participation of some key founders, including W.O. Baker, M.E. Fine, R. Roy, D.K. Stevens, C.G. Suits, and C.F. Yost.

The 22 technical symposia were, of course, the focus of the meeting, and this year offered the return of ongoing successful MRS symposia, including symposia on Beam-Solid Interactions and Transient Processes, High-Temperature Ordered Intermetallic Alloys, Graphite Intercalation Compounds, Scientific Basis for Nuclear Waste Management, Fly Ash and Coal Conversion By-Products, Microstructural Development During Hydration of Cement, and Fractal Aspects of Materials. New topics or topics that have been a long time in reappearing at the meeting included Advanced Structural Ceramics; Scattering, Deformation and Fracture in Polymers; Materials Processing in the Reduced Gravity Environment of Space; Optical Fiber Materials and Properties; Solitons in Materials Science; and numerous others. The following summaries report the highlights of many successful symposia. If an Extended Abstracts volume is available or a Proceedings is to be published, this information is also provided.

As a record of the success of the 1986 Fall Meeting, this report is all too brief; and, therefore, you are encouraged to refer to the details published in the 3 Extended Abstracts and upcoming 17 Proceedings volumes, and to make plans to attend the two 1987 MRS meetings under preparation—the Spring Meeting (April 21-25, Anaheim, CA) and the Fall Meeting (November 30-December 5, Boston, MA).

1986 MRS Awards Committee Chairman E.N. Kaufmann presents the Von Hippel Award to M. Balkanski.

Beam-Solid Interactions and Transient Processes (Symposium A)

Symposium Organizers: S.T. Picraux (Sandia National Laboratories), M.O. Thompson (Cornell University), and J.S. Williams (Royal Melbourne Institute of Technology)

Symposium A on the Fundamentals of Beam Solid Interactions has been held annually for the last seven years and originally ushered in the era of laser annealing. The symposium continued its tradition of presenting new and stimulating results. The emphasis of this year's symposium was on the processes which take place in solids due to intense excitation by laser, ion, and other energy beams with the timescales ranging from femtoseconds to seconds. Although the emphasis was on fundamentals, there is a continuing exploration of the technological implications of these processes for materials applications. This year more than 110 papers were presented in four days of oral sessions plus one poster session. Due to constraints of time and space, only about 70% of the submitted abstracts could be included in the program. Peak attendance exceeded 300 people.

A number of notable results were presented at this year's symposium. In the opening joint plenary session with Symposium B, B.R. Appleton (Oak Ridge National Laboratory) discussed the use of ion beams at some tens of eV to directly clean single crystal surfaces and grow isotopically pure epitaxial layers. J. Greene (University of Illinois) discussed the use of low

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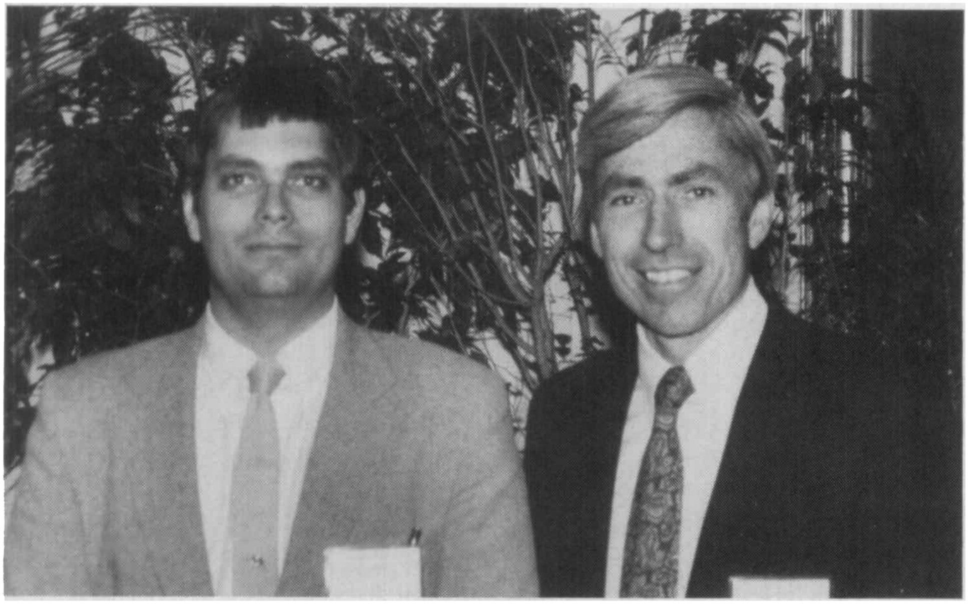

Symposium A Organizers (left to right): M.O. Thompson and S.T. Picraux. (Not shown, J.S. Williams)

energy ions to modify growth processes, including nucleation, surface mobility, and segregation processes of epitaxial layers. H. Kurz (Technical University-Aachen) discussed recent results on the fundamental limits of energy deposition and confinement by extremely fast laser irradiation. New understanding of fast cooling mechanisms, such as plasma-assisted recombination, is emerging at these short times and high levels of excitation. R. Osgood (Columbia University) concluded the plenary session with an excellent overview of new developments in the use of optical excitation for controlled processing of electronic materials.

A second joint plenary session was held with Symposium G to address the question of rapid solidification processes. P. Peercy (Sandia National Laboratories) discussed the latest results in the direct measurements of interface velocities versus undercooling in silicon. He demonstrated a consistent body of knowledge clearly showing the strong asymmetries between melting and freezing and the need for new advances in the fundamental theory of solidification. M. Aziz (Harvard University) summarized the understanding of and presented new theoretical predictions on the influence of solutes on moving interfaces. W. Boettinger (National Bureau of Standards) surveyed the latest understanding of rapidly solidified microstructures and A. Berkowitz described the spark erosion process of forming rapidly solidified powders.

Other sessions were held on thermodynamics and kinetics of laser-solid interactions, laser modification of materials, phase transformations, ion mixing and implantation, rapid thermal annealing, and silicon-on-insulator materials. In laser studies J. Bruines (Philips Research Laboratories) discussed the current understanding of metastable transitions in amorphous silicon and new measurements on the explosive crystallization process. Other contributions ranged from new theoretical approaches on melting and freezing in Si to the first measurements of the melting point of an icosahedral phase. Laser interactions with materials other than semiconductors are becoming increasingly important. E. Marinero (IBM Almaden) discussed the interaction of lasers in Te and GeTe alloys, materials important for optical recording applications. Y. Goto et al. (Fujitzu Laboratories) described the first results for crystal-to-crystal transformation in optical recording media. Other new topics included the irradiation of polymers and the influence of ambients on the laser modification of surfaces.

In research involving ion beams, E. Nygren (RMIT), as well as AT&T Bell Laboratories and Hughes Research Laboratories workers, described the rapidly emerging understanding of high implanted concentrations of solutes in amorphous silicon. Enhancements in solubilities as much as six orders of magnitude and extremely fast nucleation processes are found relative to crystalline silicon. R. Averbach (Argonne National Laboratories) reviewed the understanding of displacement cascades in the ion-beam modification of materials. He presented new results illustrating the rapid progress being made with molecular dynamics calculations in understanding the microscopic details of collision cascade evolution and the ion beam mixing process. In a post deadline paper A. White (AT&T Bell Laboratories) described the first formation of a buried heteroepitaxial metallic layer in Si by ion implantation of Co and demonstrated interface sharpening similar to that for buried oxide layers upon annealing.

Rapid thermal annealing (RTA) elicited much interest in limited reaction processing, which combines RTA with chemical vapor deposition to produce sharp interfaces and doping profiles. Reviewing the latest developments in this area, J. Gibbons and C. Gronet (Stanford University) presented results demonstrating strained SiGe/Si heterostructural growth and Si doping profiles with a concentration profile abruptness as sharp as one decade per 40 Å.

The symposium ended with a session on growth and characterization of silicon-on-insulator (SOI) materials. L. Pfeiffer (AT&T Bell Laboratories) reviewed the current understanding of mechanisms occurring during crystallization of SOI films from the melt. Results of SOI fabrication by ion implantation were also presented. Both oxide- and nitride-containing structures are being pursued; and high-temperature thermal annealing processes, along with dislocation and impurity reduction, remain key issues in the implanted structures. The large attendance at this last session indicates the strong materials science interest in this area.

In summary, the symposium addressed important fundamental issues relating to beam-solid interactions. An outstanding array of invited and contributed papers not only illustrated how our understanding of the fundamental processes has matured, but also demonstrated a number of new surprises and exciting developments in this important area of materials science.

Symposium Support: Defense Advanced Research Projects Agency (S. Roosild), AT&T, IBM, Universal Energy Systems, Inc.

Proceedings: Volume 74 of the Materials Research Society Symposia Proceedings series

Photon, Beam and Plasma Stimulated Chemical Processes at Surfaces (Symposium B)

Symposium Chairmen: V.M. Donnelly (AT&T Bell Laboratories), I.P. Herman (Columbia University), and M. Hirose (Hiroshima University)

This symposium highlighted recent advances in the rapidly expanding use of lasers, ion beams, and plasmas to enhance chemical processes at surfaces. A variety of work was reported, ranging from very fundamental studies of the modification of surface chemistry, to applications in VLSI and optoelectronic devices.

The symposium began with a joint plenary session with Symposium A (Beam-Solid Interactions), featuring four talks on ion- and photon-induced processes. B.R. Appleton (Oak Ridge National Laboratory) reported some very unusual effects in low

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energy ion beam deposition. He found that 40 eV Ge ions impinging on Si at 400°C create a band of anomalously deep damage (60–160 nm), but no damage at the surface. He also found that Si homoepitaxial films can be deposited with 20 eV ions at 600°C on n-type substrates, while amorphous films deposit on p-type Si, under otherwise identical conditions. J. Greene (University of Illinois) described the influence of ion bombardment on diffusion and nucleation. He found that In grows preferentially along <110> directions on Si (100) 2 × 2 surfaces. However, if the surface is damaged by ion bombardment, then no preferential growth direction is observed. He also showed that ion bombardment causes In deposits on Si_3N_4 to coalesce into large islands, due to dissociation of small In particles on the surface and the resulting enhanced mobility. H. Kurz (Technical University-Aachen) described ultrafast fundamental processes at high laser excitation levels ($\geq 10^{20}$ cm^{-3}). Among the many phenomena described, he reported that extremely large electron temperatures and velocities ($\sim 10^8$ cm s^{-1}) can be achieved in metals, so that thermal spreading from laser irradiation can be much larger (several microns) than normally expected based on the thermal diffusion via phonon interactions. Finally, R. Osgood (Columbia University) gave an overview of laser chemical processing, in particular on the role of electron-hole pair excitation ion etching and oxidation.

A second plenary session was held jointly with Symposium C (Science and Technology of Microfabrication). D. Ehrlich (MIT Lincoln Laboratory) gave an overview of laser-projection patterning for broad area deposition and etching of thin films. The motivation behind this approach is to reduce the number of processing steps in pattern transfer and eliminate air exposure at critical steps in device fabrication, where interfacial defects and dopant segregation cannot be tolerated. Y. Horiike (Toshiba) reviewed the lithography and etching of submicron features for the next several generations of dynamic RAMs (4, 16, 64, and 256 Mbit). He predicted that excimer lasers may be used in the near future for photoresist exposure, with the technology ultimately evolving to the use of synchrotron radiation for ~0.1 μm linewidths. A. Bernhardt reviewed Lawrence Livermore National Laboratory work using lasers to write nickel and doped polysilicon lines for custom interconnections in gate arrays. Writing speeds of 1 mm/s were achieved, and fully functioning circuits were demonstrated. The session ended with a talk by A. Wagner (IBM) on the use of focused ion beams for mask repair. Liquid Ga focused ion beams can be used to remove unwanted material by sputtering, or to render clear areas nontransmitting by micromachining a prism into the quartz substrate.

Symposium B Organizers (left to right): M. Hirose, I.P. Herman, and V.M. Donnelly.

The other sessions of the symposium consisted of invited and contributed talks and poster session papers covering a wide range of related topics. Laser-induced metal deposition received much attention. G. Higashi (AT&T Bell Laboratories) discussed nucleation effects in laser-initiated deposition of conducting, patterned aluminum films. Y. Nissim (CNET) discussed similar observations. Higashi also fabricated FETs from this localized metallization technique. Other workers reported direct writing of metal lines with a scanned, focused laser beam. For example, S. Bezuk (Sperry) talked about deposition of nickel on polyimide, while R. Sausa (IBM), M. Gross (AT&T Bell Laboratories), and V. Houlding (Allied-Signal) discussed pyrolytic deposition of metals from metal-containing organic films.

Laser-induced growth of Si, Ge, and III-V compound semiconductor films is receiving increasing interest. Two optical diagnostics papers were presented on the growth of Si. B. Drevillon (Ecole Polytechnique, France) reported *in situ* ellipsometry studies of the nucleation and growth of plasma-deposited amorphous silicon films, while T. Heinz (IBM) discussed the use of second harmonic generation as a probe of the surface structure during growth and heat treatment of silicon layers. Growth of GaAs films was reported by J. Zinck (Hughes), V. McCrary (AT&T Bell Laboratories), N. Karam (North Carolina State), Y. Aoyagi and co-workers (Institute of Physical and Chemical Research, Japan), and J. Warner (NASA Lewis).

Etching studies were also well represented. H. Winters (IBM) presented a modified Mott-Cabrera mechanism to explain the effects of doping level and type on etching of silicon by XeF_2. M. Hirose (Hiroshima University, Japan) and J. Yarmoff (IBM) reported photoelectron spectroscopy data showing the complex nature of the fluorinated silicon surface. A mixture of every species from SiF to SiF_4 is found in a ~10 Å surface layer. N. Selamoglu (AT&T Bell Laboratories) reported ~100 fold enhancements in silicon etching by F_2 in the presence of a thin layer (approximately several monolayers) of copper on the surface. This is the first known report of catalyzed etching.

Etching of compound semiconductors also received much attention. C. Ashby (Sandia National Laboratories) discussed the effects of doping levels and substrate bias voltages on photochemical etch rates of GaAs and GaAsP downstream from an HCl discharge. Other workers described ion beam and solution phase etching. Several papers were presented on novel ion beam chemical processing. For example, L. Harriot (AT&T Bell Laboratories) reported focused ion-beam-induced palladium deposition from palladium acetate thin films. S. Todorov (Columbia Unversity) presented impressive results on the growth of continuous, ultrathin, high quality (40–50 Å) SiO_2 films grown by room temperature oxidation of silicon with a low energy ion beam.

This year's symposium reflected the growing interest in understanding the basic chemistry associated with photon or charged-particle enhanced processing. Several of the above-mentioned papers reflected this trend. In addition, J. Yates (University of Pittsburgh) presented detailed studies of ion bombardment modification of the reactivity of a Si (100) surface with propylene. Other researchers reported studies of both thermal and photo-

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chemical decomposition of molecules adsorbed on surfaces, the role of electron bombardment in promoting reactions and desorption, and Monte Carlo simulations of nucleation kinetics in direct laser writing. Applications of laser-chemical processing to microelectronics device fabrication was highlighted by a special session, in addition to work presented in other sessions. T. Sigmon (Stanford University) discussed the use of excimer lasers in selective area doping of silicon. The process involves laser melting of silicon in the presence of a contact mask (patterned SiO_2) and a dopant gas which is adsorbed on the silicon surface. Numerous types of silicon microelectronic devices have been fabricated by this technique. J. Black (MIT Lincoln Laboratory) reported custom metallization of GaAs integrated circuits by a laser-direct-written tungsten process. A.W. Johnson discussed work at Sandia National Laboratories in laser writing of metal lines and etching on silicon integrated circuits for customization applications. Several papers were also presented on etching of gratings for optics applications including fabrication of distributed feedback semiconductor lasers.

Finally, several novel uses of plasma in the treatment and deposition of thin films were reported. For example, H. Heinecke (Technical University-Aachen) reported plasma-assisted growth of epitaxial InP. Using plasma decomposition of PH_3, stoichiometric, epitaxial films were obtained at lower PH_3-to-triethylindium ratios and lower substrate temperatures. This excellent work was honored with one of the graduate student awards.

Symposium Support: Air Force Office of Scientific Research

Supplemental Symposium Support: AT&T Bell Laboratories, Anelva Corporation, Coherent Inc., Lambda Physik, Lumonics Inc., Matsushita Electric Industrial Co., Mitsubishi Electric Corporation, Questek

Proceedings: Volume 75 of the Materials Research Society Symposia Proceedings series

Science and Technology of Microfabrication (Symposium C)

Symposium Organizers: R.E. Howard (AT&T Bell Laboratories), E.L. Hu (University of California), S. Pang (MIT Lincoln Laboratories), S. Namba (Osaka University)

This symposium, presented for the first time at a Materials Research Society Meeting, elicited an extremely gratifying response in papers submitted and in attendance. Some sessions had standing-room-only attendance. The subject material ranged from nanofabrication techniques (extremely high resolution lithography and pattern transfer) to enable research in nanophysics, to the consideration of innovative processing and materials systems that are being incorporated into the fabrication of present-day VLSI circuits. Consideration of process-induced damage was treated. Applications of microfabrication to high performance electronic devices, sensors, and micromachined mechanical structures were discussed.

Symposium C was initiated by a plenary session held jointly with Symposium B (Photon, Beam and Plasma Stimulated Chemical Processes at Surfaces). D. Ehrlich (MIT Lincoln Laboratories) gave an impressive overview of emerging beam technologies for pattern delineation and transfer that will enable totally *in situ* processing of devices. Other talks at the plenary session demonstrated that some of those beam techniques have reached a level of maturity where they are being incorporated, or are close to being incorporated, into manufacturing schemes. A. Bernhardt (Lawrence Livermore National Laboratories) described the use of laser-induced deposition of nickel and doped polysilicon to perform custom interconnection of CMOS gate arrays. A. Wagner (IBM) discussed mask repair utilizing focused ion beams. Y. Horiike (Toshiba VLSI Research Center) spoke on microfabrication technologies being considered for advanced VLSI devices, such as a 4 Mbit DRAM (having linewidths of 0.8 μm minimum features). He discussed work being carried out on a high-throughput electron-beam lithographic machine, on a step-and-repeat exposure tool utilizing an excimer-laser source, and on focused ion beams. He also described work on magnetron reactive ion etching and excimer laser etching.

Other invited speakers highlighted the different topical themes of the symposium: W.W. Skocpol discussed the studies of localization and single electron trapping made possible with submicron MOSFETs. G. Kaminsky and K. Peterson discussed micromachining of silicon structures and the use of micromachined, silicon-based structures as sensors. M. Isaacson spoke on the fundamental limits of electron beam microfabrication, and A.K. Sinha discussed various present innovations and future needs for materials and processes in VLSI fabrication. The "formal" sessions of the symposium were augmented by a poster session. Nearly 30 poster papers were presented at this successful session, stimulating much direct interaction. Interested attendees filled the room until well past the session's close.

This first presentation of Symposium C on the Science and Technology of Microfabrication was quite successful: the papers submitted and presented covered wide, crossdisciplinary areas of interest ranging from techniques for fabrication to analysis and utilization of microstructures. As indicated by the common plenary session, there is commonality of interest with other MRS symposium topics, but with a particular emphasis not represented before. Attendance and participation were high, resulting in a good interchange of ideas.

Symposium Support: Applied Materials, CIBA-GEIGY, JEOL USA, MKS Instruments Inc., Office of Naval Research

Proceedings: Volume 76 of the Materials Research Society Symposia Proceedings series

Symposium C Organizers (left to right): E.L. Hu, R.E. Howard, S. Namba, and S. Pang.

Advanced Structural Ceramics (Symposium E)

Symposium Organizers: P.F. Becher (Oak Ridge National Laboratory), M.V. Swain (Commonwealth Scientific and Industrial Research Organization), S. Sōmiya (Tokyo Institute of Technology)

This symposium brought together researchers from around the world to discuss

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Equipment Exhibit.

the behavior of transformation-toughened and whisker/fiber-reinforced ceramics. The first part of the symposium centered on various characteristics of the tetragonal-to-monoclinic martensitic phase in zirconia and its contribution to stress-induced transformation toughening and plasticity. The mechanisms involved were highlighted by invited lectures by B.C. Muddle (Monash University), I-W. Chen (University of Michigan), and J. Lankford (Southwest Research Institute). The participants then considered recent developments in new zirconia alloy and composite systems, and microstructural aspects of such systems. Invited lectures by T. Takahata (Toya Soda Research Center) and F. Lange (University of California, Santa Barbara) accentuated recent advances in these areas.

The latter portion of the symposium focused on reinforcement of ceramics by the incorporation of fibers and whiskers. Excellent overviews of the advances in understanding of the toughening and strengthening behavior and in developing such composite systems were provided in invited lectures by D. Marshall (Rockwell International Science Center), P. Angelini (Oak Ridge National Laboratory), and A. Evans (University of California, Santa Barbara).

The symposium afforded an opportunity to exchange ideas and discuss the current state of our understanding of processes leading to the significantly enhanced fracture toughness of these materials and their related deformation and strength behavior. Recent advances in developing such toughened ceramics, either transformation-toughened or whisker/fiber-reinforced ceramics, have shown that the fracture toughness of ceramics can be increased fivefold or more. It was clear from the discussions that the continued progress in our understanding of the processes contributing to the toughening and related mechanical behavior have had a significant impact in these developments. The result has been the generation of new and advanced classes of ceramics for structural applications.

Symposium Support: Office of Basic Energy Sciences, Division of Materials Sciences, U.S. Department of Energy

Proceedings: Volume 78 of the Materials Research Society Symposia Proceedings series

Scattering, Deformation and Fracture in Polymers (Symposium F)

Symposium Organizers: B. Crist (Northwestern University), T.P. Russell (IBM Almaden Research Center), E.L. Thomas (University of Massachusetts) and G.D. Wignall (Oak Ridge National Laboratory)

The symposium on Scattering, Deformation and Fracture in Polymers began with a tutorial session on the fundamental physics of scattering of electromagnetic radiation with an emphasis on x-ray and neutron scattering. These tutorials were designed to introduce those not familiar with scattering to the basics of scattering and to show the application of scattering in a wide spectrum of problems in polymer science. Following this, the symposium was divided into two parts, with three sessions concentrating on the current use of scattering methods in polymer research and three sessions dealing with research in deformation, fracture, and fatigue in polymers. The speakers in these sessions were all invited, the intent being to present the most outstanding research.

The response to the contributed poster session indicated that the primary goal of the symposium was achieved. The poster session had over 40 contributions representing work from a wide range of disciplines in polymer science. Attendance at both the invited sessions and poster sessions was excellent, with audiences of more than 100 at each session. As an additional highlight, two of the speakers, K.P. McAlea and A.Y. Lee, received graduate student awards from the Materials Research Society.

The symposium proceedings volume will be dedicated to the memory of W.C. Koehler, one of the leaders in the development of the National Center for Small Angle Scattering Research at Oak Ridge National Laboratory.

Symposium Support: Petroleum Research Fund of the American Chemical Society; Office of Basic Energy Sciences, Division of Materials Sciences, U.S. Department of Energy; Air Force Office of Scientific Research; IBM Corporation

Co-Sponsor: American Chemical Society, Division of Polymer Chemistry

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Science and Technology of Rapidly Quenched Alloys (Symposium G)

Symposium Organizers: M. Tenhover (Standard Oil), W.L. Johnson (California Institute of Technology) and L.E. Tanner (Lawrence Livermore National Laboratory)

This symposium covered the fundamental and technological aspects of rapidly quenched metallic alloys. It consisted of four oral sessions and one poster session on topics related to the formation, properties, and applications of amorphous and microcrystalline alloys. In addition, the second day featured a joint plenary session with Symposium A (Beam-Solid Interaction and Transient Processes). This joint session, entitled Rapid Solidification Processes, was very well attended.

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Symposium E Organizers (left to right): M.V. Swain, P.F. Becher, and S. Sōmiya.

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Symposium F Organizers (left to right): E.L. Thomas, G.D. Wignall, T.P. Russell, and B. Crist.

In the first invited talk of the symposium, L. Schultz (Siemens AG) reviewed the exciting new methods for the direct production of amorphous metal powders. His talk focused on mechanical alloying using high energy ball mills to form Ti- and Zr-based amorphous transition metal alloys. Various measurements were used to determine the amorphous nature of the alloys, including x-ray diffraction, annealing studies, and differential scanning calorimetry. In one interesting series of experiments, alloys of the form $Zr_{40}X_{60}$ were investigated. It was reported that when X = Cu, Ni, Co, Fe, and Mn, completely amorphous metal alloys could be formed by mechanical alloying. When X = Cr and V, only crystalline materials were observed. These results illustrated the importance of the heat of mixing of the two components in the alloy in solid-state reactions.

In the other invited talk of the first session, R. Henderson (Standard Oil) outlined a broad range of chemical methods to form amorphous metal alloys. These processes, reported for the first time at this symposium, are based on the thermal or chemical decomposition of metal-containing compounds to form intimate mixtures of metals and metalloids that were transformed to amorphous metal powders. Several new results of this work, such as the direct fabrication of multicomponent powders and the synthesis of ultrafine (10 nm size) amorphous powders, were described.

Symposium G Organizers (left to right): M.A. Tenhover and W.L. Johnson (Not shown, L.E. Tanner.)

B. Dolgin (Allied-Signal) reported on the mechanical alloying of Ti-Fe, Ti-Co, and Ti-Ni to form amorphous powders. The addition of toluene in a wet-milling process greatly enhanced the rate of amorphous alloy formation. C. Politis (Kernforschungszentrum Karlsruhe) and J. Thompson (University of Tennessee) also reported on the production of amorphous metal alloy powder, this time Pd-Si and Ti-Pd compositions. For Ti-Pd, they reported that conventional rapid quenching methods led to microcrystalline alloys while mechanical alloying successfully produced completely amorphous powder over a wide range of Ti content (42–85%). They and other authors in this session concluded that the nature of amorphous metal formation differs in the mechanical alloying process from that in liquid quenching from the melt.

M. Atzmon and F. Spaepen (Harvard) and E. Chason, T. Mizoguchi, and H. Kondo (Gakushuin University) described experiments using compositionally modulated metallic films to study solid-state reactions and atomic transport in amorphous metals. E. Kamentzky (Lawrence Berkeley Laboratory) described a new phenomena, the deformation-induced amorphization of crystalline particles in melt-spun Cu-Ti ribbons. The amorphous metal formed in the deformation process appears to nucleate at the particle/amorphous metal interface.

Other methods of amorphous metal formation such as high velocity injection (C. Hays, Texas A&M University), spark erosion (J. Walter, General Electric), and confined gas atomization (R. Raman, GTE Laboratories) were also described.

The second session opened with two distinguished speakers, N. Grant (MIT) and S. Das (Allied-Signal), who discussed the technologically important area of microcrystalline alloys. Grant discussed a variety of Mg and Al alloys prepared by both the consolidation of atomized powders and by direct consolidation by the liquid dynamic compaction (LDC) process. The importance of oxygen on the powder surfaces in affecting the strength and toughness of the alloys was discussed. Das reviewed the properties and commercial aspects of Allied's microcrystalline high-strength Al-based alloys. Several authors discussed the effects of rapid solidification processing on the mechanical properties and microstructures of Ti- and Al-based microcrystalline alloys. P.R. Munroe (University of Birmingham) described laser surface melting and melt spinning effects on Ti-C and Ti-Er-C alloys. B. Muddle (Monash University) talked about microstructure work on Al-Ti, Al-B, and Al-B-Ti alloys.

The second day opened with a joint plenary session on Rapid Solidification Processes with Symposium A. P. Peercy

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(Sandia National Laboratories) gave a detailed discussion of the melt and solidification dynamics of pulsed laser melted Si. Techniques were described to measure the solidification velocity, melt depth, and other important aspects of laser processing. M. Aziz (Harvard) gave a lively presentation on nonequilibrium interface kinetics during rapid solidification. He described the fate of solute atoms during rapid solidification and topics such as impurity incorporation and interfacial undercooling. W. Boettinger (National Bureau of Standards) discussed the wide variation in microstructures observed in rapidly solidified materials. Materials discussed ranged from amorphous solids to coarse-grained crystalline solids. A. Berkowitz (General Electric) concluded the plenary session with a review of the technology and resultant materials produced by spark erosion. In this technique, fine powders (5 nm) can be produced from many different metals, alloys, and semiconductors.

Graduate Student Award Winners. Bottom row (left to right): H. Heinecke, A.Y-J. Lee, R.N. Bicknell, Y-T. Cheng, L.P. Allen, D.W. Susnitzky, C.M. Greenlief. Top row (left to right): G. Xiao, K.P. McAlea, M.R. Libera, S. M. Schlorholtz, H.A. Atwater, P.F. Miceli, and K. Holloway.

Two sessions dealt with the novel magnetic properties of rapidly quenched metal alloys. M. McHenry (MIT) opened the first session on magnetic materials with a fascinating discussion on icosahedral symmetry and magnetism. Icosahedral structures, also called quasicrystalline materials, are predicted to have some unique magnetic properties based on McHenry's symmetry arguments. The icosahedral point group leads to an enhanced density of d-states, potentially soft magnetic properties, and unique magnetic domains. The search for quasicrystalline magnetic materials is in progress. McHenry described some guidelines for what should constitute an icosahedral magnetic alloy, but at present no examples have been confirmed. C.L. Chien (Johns Hopkins) described the fabrication of new metastable body-centered-cubic alloys (Fe-Mo, Fe-Cu). These systems are ideal for studying magnetic percolation effects as a function of composition. The results reported were in excellent agreement with conventional percolation theories.

P. Rudkowski (McGill University) reported on some detailed and careful work on the effect of P on the magnetic properties and thermal stability of Fe-Si-B glasses. Small additions of P (0.1–0.2 at. %) proved beneficial to many properties of the alloys designed for power transformer applications. D.M. Kroeger (Oak Ridge National Laboratory) also described work on the effects of small additions to Fe-Si-B glasses. The system studied was Ce additions (100 at. ppm), and some remarkable improvements in resistance to embrittlement were described.

Several papers described work on icosahedral/quasicrystalline alloys based on Al-Mn. D. Baxter (McGill University) reported resistivity and magnetic susceptibility measurements on icosahedral Mg-Al-Zn alloys and compared these results with those of similar metallic glasses (Mg-Zn). The icosahedral phase materials exhibited a significantly stronger compositional dependence compared to the metallic glasses. An interesting side-benefit of this work was the determination of the absolute resistivity of the sample independent of the sample geometry.

U. Koster (University of Dortmund) addressed surface crystallization in Co-B and Fe-Ni-B metallic glasses. Heterogeneous nucleation can occur at both the free surface and wheel side of melt spun ribbons. This leads to crystallization at temperatures significantly below any crystallization event in the bulk glasses.

The second session on the magnetic properties of rapidly quenched metals focused on applications of permanent or hard magnetic materials. J. Croat (General Motors) described the development of microcrystalline Nd-Fe-B alloys. The coercive mechanism that dominates these materials is domain-wall pinning at the interfaces between essentially single magnetic domain particles. Croat described the three generations of Magnequench™ materials that will be produced having energy products of 8–9 MGOe (MQ-I, isotropic), 13–15 MGOe (MQ-II, hot pressed), and 20–40 MGOe (MQ-III, anisotropic hot formed). A.M. Kadin (Ovonic Synthetic Materials Co.) reviewed the basic requirements of permanent magnetic materials and focused on the development of potentially low cost isotropic magnetic alloys. Ovonic's Hi-REM™ materials had surprisingly high energy products (20 MGOe) for isotropic structures. F. Luborsky (General Electric) outlined the advantages and problems of magneto-optic recording using amorphous transition metal rare-earth alloy films. The issues of stability, resolution, sensitivity, and information density were expertly described. In three separate papers, M. Mansuripur, M. Ruane, and D. Chakravartty (Boston University) reported work on the preparation, mechanism, and characterization of amorphous TbFe magneto-optic alloys.

The Tuesday night poster session, with over 20 posters, covered areas from amorphous metal catalysis to amorphous metal hydrides and energetic treatments of metallic surfaces.

Symposium Support: Standard Oil Company
Proceedings: Volume 80 of the Materials Research Society Symposia Proceedings series

Characterization of Defects in Materials (Symposium I)

Symposium Organizers: R.W. Siegel (Argonne National Laboratory), R. Sinclair (Stanford University), J.R. Weertman (Northwestern University)

The 85 papers presented during this symposium brought to the attention of the materials research community a variety of some of the most interesting and potentially useful new experimental and theoretical methods for characterizing defects in materials. Broadly interdisciplinary, the symposium considered a wide range of techniques, defects, and materials. Four half-day oral sessions were held on atomic defects and aggregates, line defects and arrays, interfaces, and surfaces. These sessions were chaired by D.N. Seidman (Northwestern University), F.W. Young, Jr. (Oak Ridge National Laboratory), R.W.

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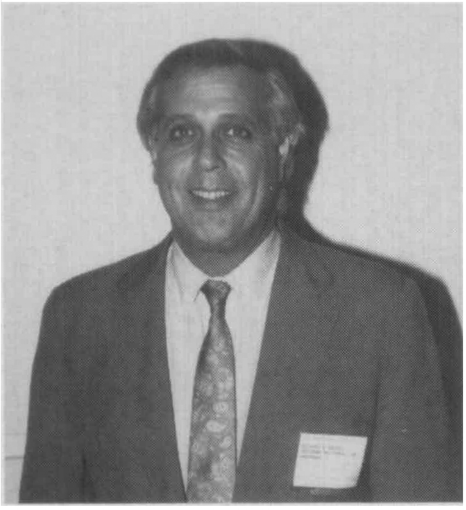

Symposium I Organizer: R.W. Siegel. (Not shown, R. Sinclair and J.R. Weertman)

Balluffi (MIT), and J.M. Blakely (Cornell University), respectively. These sessions were followed by a well-attended and stimulating poster session on defect characterization, during which 51 papers were presented. This session was chaired by J. Bentley (Oak Ridge National Laboratory), M.G. Burke (University of Pittsburgh), C.B. Carter (Cornell University), J.M. Gibson (AT&T Bell Laboratories), L.D. Marks (Northwestern University), and D.A. Smith (IBM Corporation).

The four oral sessions included invited and contributed papers chosen to highlight particularly useful characterization methods in a variety of materials. The invited papers, their authors, and affiliations were as follows:

"Defect Agglomeration in Transition Metal Monoxides," J.B. Cohen (Northwestern University)
"Positron Annihilation Spectroscopy of Defects in Solids," P. Hautojärvi (Helsinki University of Technology)
"Characterization of Defect Structures by Perturbed Angular Correlation Technique," Th. Wichert (University of Konstanz)
"TEM, Cathodoluminescence and Polarization Studies of Dislocations in Semiconductors," J.C.H. Spence, R. Graham, H. Alexander, N. Yamamoto, and D. Shindo (Arizona State University) "Synchrotron X-Ray Topography of Dislocation Arrays," J.C. Bilello (California State University, Fullerton)
"Dislocation Dynamics Investigated by Means of Nuclear Magnetic Resonance: A Complementary New Technique," J.Th.M. De Hosson (University of Groningen) and O. Kanert (University of Dortmund)
"High-Resolution Electron Microscopy of Grain Boundaries in Oxides," K.L. Merkle (Argonne National Laboratory)
"Diffraction Studies of the Structure of Grain Boundaries," M.R. Fitzsimmons and S.L. Sass (Cornell University)
"Correlation of Electrical Properties with Structure Imaging of Semiconductor Interfaces," J.L. Batstone, J.M. Gibson, A.E. White, K.T. Short, R.T. Tung, and A.F.J. Levi (AT&T Bell Laboratories)
"Tunneling Microscope Studies of New Structures on Semiconducting Surfaces," J.A. Golovchenko (AT&T Bell Laboratories)
"High-Resolution Electron Microscopy of Surfaces," D.J. Smith (Arizona State University)
"Grazing Incidence X-Ray Scattering Studies of Surfaces and Interfaces," K.S. Liang, G.J. Hughes, and P.M. Eisenberger (Exxon Research and Engineering Co.)

Symposium Support: Blake Industries, Inc.; EG&G ORTEC; Hitachi Scientific Instruments; JEOL USA; Perkin-Elmer/Physical Electronics Division; Philips Electronic Instruments, Inc.; VG Instruments, Inc.

Proceedings: Volume 82 of the Materials Research Society Symposia Proceedings series

Physical and Chemical Properties of Thin Metal Overlayers and Alloy Surfaces (Symposium J)

Symposium Organizers: D.M. Zehner (Oak Ridge National Laboratory), G.W. Goodman (Sandia National Laboratories)

This symposium focused on recent developments in both experimental studies and theoretical modeling of the fundamental properties of solid surfaces covered with thin metal overlayers as well as surfaces of multicomponent systems. Of primary interest in this symposium were studies of well-characterized surfaces which examined the atomic structure, electronic properties, and/or the surface chemistry of these systems. The five-session symposium, which consisted of 13 invited and 32 contributed papers, was very well attended and was accompanied throughout by active discussions.

The first session, Structure and Electronic Properties of Alloy Surfaces, was led off by Harold Davis (Oak Ridge National Laboratory). He discussed work on the atomic structure of binary metal alloy surfaces using state-of-the-art Low Energy Electron Diffraction (LEED) and Rutherford backscattering of ions (RBS) measurement techniques coupled with computer simulation and analysis. Specific effects discussed included the rippling of atomic constituents in the surface layers of ordered alloys and the preferential termination of alloys by a specific type of layer where more than one type of layer exists in the bulk. In a second invited paper W. Plummer (University of Pennsylvania) presented his group's work on photoemission studies from ordered alloys, principally single crystal surfaces of NiAl and TaC(001), and compared these results with recent theoretical calculations. Contributed papers in this session included a contribution from F. Jona (State University of New York, Stony Brook) and P. Marcus (IBM Yorktown Heights), who discussed the growth of ultrathin epitaxial films of bcc Ni on Fe(001) studied by LEED and Auger spectroscopy (AES). Another contributed paper by R. Hauert, P. Oelhafen, and H. Guntherodt (University of Basel, Switzerland) discussed the influence of the alloy electronic structure on the chemisorbed CO molecule. The alloys of interest in these studies were Ni, Pd, and Ir alloyed with electropositive elements such as Zr and Y or Si and Al.

The second session, Structure and Elec-

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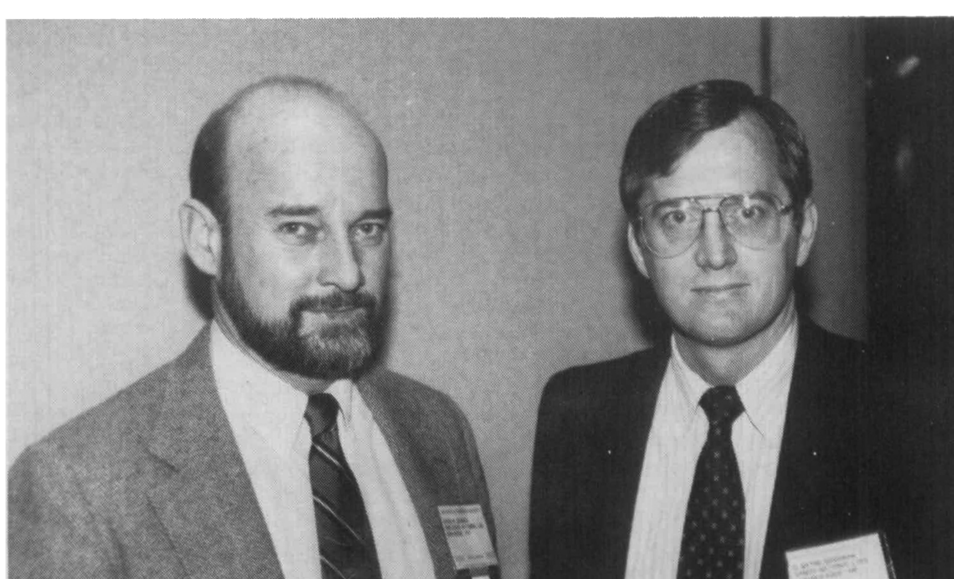

Symposium J Organizers (left to right): D.M. Zehner and G.W. Goodman.

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tronic Properties of Thin Metal Overlayers, began with an invited talk by M. Ruckman and M. Strongin (Brookhaven National Laboratories) which described work on modifying the properties of metal overlayers adsorbed onto Nb(110) and Ta(110). An invited paper from J. Houston (Sandia National Laboratories) discussed Angle Resolved Ultraviolet Photoemission (ARUPS) studies of the interaction of CO with the interface state for strained-layer Cu on Ru(0001). H. Metiu (University of California, Santa Barbara) followed with an invited paper summarizing his group's work on the chemisorption properties of bimetallic systems studied by metastable quenching (Penning) spectroscopy. A fourth invited paper by F. Hoffman and J. Paul (Exxon Research and Engineering) described research using infrared absorption spectroscopy to study CO adsorbed onto Cu overlayers on Ru(0001).

The third session, Structure and Chemistry of Thin Metal Films, was highlighted with invited talks from J.M. White (University of Texas), B. Koel (University of Colorado), and P. Berlowitz (Sandia National Laboratories). White discussed his group's work on the growth and properties of thin metal films on metal and metal oxide supports. Koel described work on the surface chemistry of thin Pd films grown on Ta and Nb. Berlowitz summarized work at Sandia on the adsorptive and reactive properties of mono- and submonolayer films of Ni on W single crystal surfaces.

The fourth session, Structure and Properties of Thin Metal Overlayers and Alloy Surfaces, was highlighted by invited talks from P. Feibelman (Sandia National Laboratories) and D. Zehner (Oak Ridge National Laboratory). Feibelman detailed his work on the theory of surface additive electronic structure, which focused on the metal overlayer system Ni/W(100). Zehner reviewed his group's work on the oxidation of NiAl surfaces studies by a variety of surface sensitive techniques.

The fifth session, Reactions at Thin Metal Interfaces, was keynoted by J. Weaver (University of Minnesota), who reviewed his group's work on reactions at metal/semiconductor interfaces. Contributed papers by S. Williams (University of California, Los Angeles) discussed work in his laboratories on the chemical stability of $AuGa_2$ films on GaAs substrates as well as chemical reactions at the Au/InP interface. The second portion of this session dealt with the use of optical second harmonic generation to describe the physical properties of alloys and thin metal overlayers. J. Hamilton (Sandia National Laboratories), presented an invited talk on this subject, describing the technique and its use to characterize surface segregants on an Fe/Cr/Mo alloy surface.

The timeliness of this symposium, the first of its kind nationally, was evidenced by attendee interest and participation. Obviously, many groups are presently making substantial efforts to define the structural, electronic, and chemical properties of thin metal films and alloy surfaces. A fundamental understanding of the relationship between the surface physical properties of these materials and the corresponding chemistry that these surfaces exhibit is clearly necessary in order to ultimately tailor materials with superior corrosive, catalytic, and wear properties.

Symposium Support: Oak Ridge National Laboratory, Sandia National Laboratories

Proceedings: Volume 83 of the Materials Research Society Symposia Proceedings series

Symposium K Organizers (left to right): M.S. Dresselhaus, G. Dresselhaus, and S.A. Solin.

Graphite Intercalation Compounds (Symposium K)

Symposium Organizers: M.S. Dresselhaus (Massachusetts Institute of Technology), G. Dresselhaus (Massachusetts Institute of Technology), S.A. Solin (Michigan State University)

The program featured a total of 82 invited and contributed papers, providing broad coverage to the field of graphite intercalation compounds (GICs), including structural properties, phase transitions, kinetics of intercalation, staging transitions, intercalant domains, electronic structure, magnetic phenomena, surface properties, charge transfer, transport properties, optical properties, phonons, superconductivity, ESR and NMR studies, ternary compounds, new materials, fibers and applications. Many advances in the field were made since the last MRS symposium on GICs in 1984. Especially noteworthy have been advances in modeling the staging kinetics and phase diagrams, in understanding the surface vs. bulk properties of GICs, in preparing and characterizing advanced mesophase pitch and vapor-grown fibrous materials, in the intercalation of these fibers, and in preparing composites based on the intercalated fibers. Applications areas have ranged from lightweight conductors, batteries, and electromagnetic shielding to the use of intercalated graphite fibers to synthesize oxide materials in fibrous form. Furthermore, the availability of intercalated fibers has made possible fundamental studies of low temperature transport, weak localization effects and metal-insulator transitions in quasi two-dimensional materials. Several excellent papers on intercalation in other host materials, such as boron nitride, clays and layered transition metal compounds, were presented. The intercalation of layered MPS_3 hosts was vividly described by Prof. Balkanski in his Von Hippel lecture.

Interest in the MRS Symposium on Graphite Intercalation Compounds has steadily increased since the first symposium in 1982. Participants were enthusiastic about scheduling a fourth symposium in the Fall of 1988, continuing the tradition of a two-year cycle. Attendance at the 1986 symposium was about 150 at peak periods, and a sizable audience was present at all times. An estimated more than 200 persons participated at some time during the three days of the symposium. Attendance from abroad has been increasing steadily since the first symposium in 1982. The high attendance at the symposia has been due to the high quality of the papers and the opportunity for discussion with the principal workers in the field. Student participation in this symposium has also continued to be very high.

One novel feature of Symposium K has

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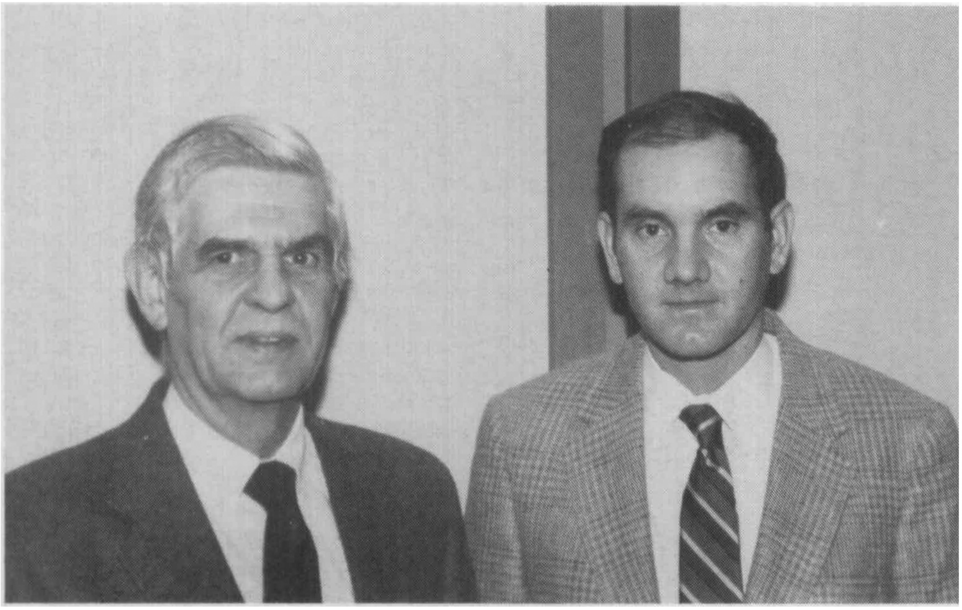

Symposium L Organizers (left to right): W.B. Seefeldt and J.K. Bates.

been the use of the lunchtime break for focused discussions of controversial or rapidly developing areas in the field. At these sessions, an attempt was made to identify areas of agreement and areas of disagreement and to suggest research areas to promote progress in the field. The first lunchtime session was devoted to structural issues, the second to electronic structure, and the third to carbon fibers and applications. Though the time was too short to fully present the controversial issues, progress in establishing the positions was significant.

Symposium Support: NASA Lewis Research Center
Extended Abstract Volume EA-8, published by the Materials Research Society

Scientific Basis for Nuclear Waste Management X (Symposium L)

Symposium Organizers: J.K. Bates (Argonne National Laboratory), W.B. Seefeldt (Argonne National Laboratory)

The 1986 symposium was the tenth in a series of international MRS Symposia devoted to the scientific aspects of nuclear waste management. The symposium theme was the long-term projection of materials interactions and performance in a high-level nuclear waste repository. Seventy-one papers were presented in oral and poster sessions.

Highlighted by the first four speakers, the symposium theme is especially important now because, as T. Jungling (U.S. Nuclear Regulatory Commission) and A. Berusch (U.S. Department of Energy) pointed out, it will form the cornerstone of an application to license a repository. L. Werme (SKB, Sweden) covered the theme from a European perspective, while J. Fond (National Bureau of Standards) highlighted informational and data base needs for predicting performance.

To commemorate the symposium's tenth anniversary and to focus attention on session topics, invited speakers reviewed the progress made in the last ten years and suggested research that is still needed. N. Bibler and C. Jantzen (Savannah River Laboratory) reviewed the interactions between glass and repository components, and noted that glass reactions were highly dependent on the repository environment. When test plans include anticipated repository conditions, such as natural groundwater and radiation, leach rates of glass may be less than obtained in conventional laboratory tests.

R. Ewing (University of New Mexico) described how natural glasses, resulting from ancient volcanic lava flows, can be used as analogs to interpret the performance of nuclear waste glasses. By studying the alteration of basaltic glass under a variety of physical conditions and fitting the results to predictive models, a correlation of observed long-term performance of natural glasses and the short-term experimental results of nuclear waste glasses can be made. According to Ewing, this analog relationship may be the only approach that will establish public acceptance of long-term performance required to demonstrate compliance to regulatory requirements.

V. Oversby (Lawrence Livermore National Laboratories) discussed the long-term performance of spent fuel, which is currently the most significant waste form for a repository. While current experimental data indicate that spent fuel is highly resistant to most leachants, it was stressed that testing must incorporate repository conditions to assess all important effects.

B. Bunker (Sandia National Laboratories) stated that while glass is the waste form that has received most attention, projections of its long-term performance still have a significant amount of uncertainty. However, Bunker estimated that the degree of uncertainty in predictive models of glass performance has been reduced by a factor of 10,000 in the last ten years.

The session on metal corrosion was introduced by a review paper on statistical issues of pitting by M. McNeil (U.S. Nuclear Regulatory Commission). The state of knowledge relating predictive pit depths with factors such as time, area, and environment was presented.

The symposium was well attended, with fourteen countries represented. International concern for a scientific basis of long-term performance predictions in nuclear waste management was apparent.

Symposium Support: U.S. Department of Energy, U.S. Nuclear Regulatory Commission
Proceedings: Volume 84 of the Materials Research Society Symposia Proceedings series

Microstructural Development During Hydration of Cement (Symposium M)

Symposium Organizers: L.J. Struble (Center for Building Technology, National Bureau of Standards), P.W. Brown (Center for Building Technology, National Bureau of Standards)

Symposium M included five sessions, each related to an aspect of microstructure, a sixth session held jointly with Symposium N (Fly Ash and Coal Conversion By-Products), and a poster session devoted to microstructure.

The first session was devoted to the pore structure of hydrated cement. Presentations covered the modeling of porosity, determination of pore structure, measurement of permeability, microstructure-permeability relationships, influence of temperature on composition and microstructure, and the relationship between cement type, pore structure, and carbonation.

Modeling microstructural development was discussed in the second session. Presentations included an overview of microstructural modeling, interpretation of pore structure using fractal geometry, the relationship between hydration product volume and stoichiometry, the effect of particle size on hydration kinetics, and the relationships involving microstructure, freezing behavior, and dynamic modulus.

A broad range of microstructural related topics were included in the poster session, including calculation of bound water as a basis for determining solution compositions, electron optical observations on sand, multimethod phase analysis of cement paste, pore structures of mortars made with sea water, epoxy impregnation

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Symposium M Organizers (left to right): L.J. Struble and P.W. Brown.

techniques, influence of $CaCl_2$ on concrete microstructure, a model of simulating ground clinker, and porosity-strength relationships.

Presentations in the joint session with Symposium N focused on microstructures of cements containing fly ash, slag, or other mineral admixtures.

Relationships between microstructure and engineering properties was the theme of the fifth session. Presentations included overviews of the influence of microstructure on the toughness of brittle materials and cement microstructure-engineering property relationships. Other contributions to this session dealt with the microstructural aspect of stress corrosion cracking, microstructure at the cement-aggregate interfacial zone, microstructure of high-performance concrete, and the relationship between fatigue failure and microstructure.

Microstructure in general was the theme of session six. Included were discussions of microstructural observations obtained using both transmission and scanning electron microscopy. The use of nuclear magnetic resonance and aqueous phase analysis in combination with electron optical methods was discussed, as was the relationship between the microstructures of anhydrous and hydrated phases.

The final session of Symposium M was devoted to the influence of chemical admixtures on microstructure. Overviews considered the analysis of cement-admixture interaction using nuclear magnetic resonance and the etiology of C-S-H formation in the presence of sugar. Other presentations discussed the effect of NaOH on tricalcium aluminate hydration, the effect of admixtures on the homogeneity of blended materials, microstructures of high-strength cements, and microstructure-property relations in expansive grouts.

Symposium Support: Army Materials Technology Laboratory, Air Force Office of Scientific Research, W.R. Grace & Co.
Proceedings: Volume 85 of the Materials Research Society Symposia Proceedings series

Materials Processing in the Reduced Gravity Environment of Space (Symposium O)

Symposium Organizers: R.H. Doremus (Rensselaer Polytechnic Institute), P.C. Nordine (Midwest Research Institute)

The highlight of this symposium was the first lecture by Taylor Wang of the Jet Propulsion Laboratory. Wang related his experiences as a scientist-astronaut on a space shuttle flight. He described his training and emphasized the importance of having on the flight project payload specialists who are principal investigators. Because his equipment did not function during the flight, he spent two days diagnosing and repairing the loss of a power supply. The equipment functioned after this repair, although not as originally planned; nevertheless, Wang was able to produce fascinating and unexpected results on the motions of fluid drops in microgravity.

Other papers emphasized the vigorous state of ground-based research on gravity-related problems. Several studies involved the influence of gravity-induced convection on crystallization processes in metals, alloys, semiconductors, organic melts, and meteorites. H.C. Gatos (MIT) described space experiments on growing semiconductor crystals and emphasized the improvement of crystal quality and homogenization by low gravity growth.

Another group of lectures described levitation studies on the ground. J.L. Margrave (Rice University) told of measurements of properties of levitated liquid metals at high temperatures. Several talks by workers at the Jet Propulsion Laboratory concerned acoustic, electrostatic, and electromagnetic levitation techniques.

A group of speakers summarized activities involving cooperation between NASA and commercial developers. A variety of projects involving crystal growth from vapor, liquid, and solution (proteins); separation techniques; and formation of monodisperse latex spheres were described, testifying to the interest and progress in cooperative programs.

Other experiments on glass, fluid flow, phase separation, and furnace design were described.

The symposium was a testimony to the increasing activity in microgravity science and technology.

Proceedings: Volume 87 of the Materials Research Society Symposia Proceedings series

Optical Fiber Materials and Properties (Symposium P)

Symposium Organizers: S.R. Nagel (AT&T Bell Laboratories), J.W. Fleming (AT&T Bell Laboratories), G. Sigel (Rutgers University), D.A. Thompson (Corning Glass Works)

This symposium, held for the first time at the 1986 MRS Fall Meeting, focused on the preparation, properties, and characterization of materials suitable for use in optical transmission, particularly in fiber form. Six invited talks and 25 contributed papers were presented in five topical sessions. The intent of the symposium was to provide a multidisciplinary forum to discuss a broad range of new materials problems.

The first session on polymer fibers and coatings began with an invited paper on plastics and polymers for optical transmis-

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Symposium O Organizer: P.C. Nordine. (Not shown, R.H. Doremus)

Symposium P Organizers (left to right): D.A. Thompson, G. Sigel, S.R. Nagel, and J.W. Fleming.

sion applications. Plastic optical fibers for such diverse applications as local area networks, data links, and endoscopes were reviewed as well as organic dye doped polymers for use as optical fiber chemical sensors, scintillating detectors, and non-invasive taps. Other polymer compositions for GRIN lenses, splitters, couplers, branching components and nonlinear optics applications were also highlighted. A second invited talk reviewed specialty fiber coating materials, including discussion of both polymer-based and ceramic coatings for silica-based optical fibers. Titanium carbide hermetic coated fibers show great promise for improving the long-term static fatigue properties of fibers and may also serve as a barrier to hydrogen, which can diffuse into fibers and adversely affect transmission losses.

Four contributed papers dealt with advances in optical fiber coatings. UV curable silicone coatings with more rapid curing characteristics are achieved through modifications to the basic formulation. A second paper reported on studies correlating the water absorption and adhesion properties of polymeric coatings to the resultant strength and fatigue properties of the fiber. Another paper discussed the use of organosilsequioxane polymer coating for improved long-term fatigue characteristics of fibers. Desirable fiber and coating characteristics required for fiber embedment in composite structures for such applications as data transmission in a nonmetallic composite aircraft structure were also reported on.

The second session on oxide glasses, processing and characterization opened with an invited talk on new oxide glasses, and was followed by seven papers on various materials aspects of oxide-based glasses. The chemistry of fluorine doping of flame-synthesized silica porous bodies was discussed for three different doping methods involving either combustion or sintering. A follow-on paper reported on a nondestructive x-ray tomography technique for characterizing both the density and composition of porous doped silica boules, which has further utility for other materials characterization.

A number of papers reported on the effect of processing on the resultant properties of silica-based glasses. For germanium silicate glasses prepared by vapor axial deposition, the germanium concentration and photoluminesce was correlated to changes in heat-treatment, specifically under different reducing conditions; in addition, defect mechanisms to explain the luminescence were proposed. For germanium silicate glasses prepared by plasma activated CVD to make planar waveguide structures, laser heating with a focused CO_2 laser beam resulted in increased refractive indices thought due to GeO formation. A direct writing technique for stripe waveguides based on this principle was proposed for this and possibly other material systems.

Sol-gel processing results were reported by two sets of investigators. The mechanical properties determined by acoustic measurements, bend tests, and thermal mechanical spectroscopy are quite different, depending on the specific gel method of preparation, and can thus impact subsequent processing steps. A specific gel methodology outlined for fabricating optical fibers which demonstrated losses as low as 5.5 dB/km at 0.84 μm. Advances in titanium-doping of lithium niobate based on ion implantation to make optical waveguide structures resulted in good waveguides with titanium concentrations not achievable by conventional techniques.

The last paper of the session described the synthesis and characterization of titanium niobium borosilicate glasses for nonlinear optical waveguides for fast signal processing, where the composition was optimized for both third-order nonlinearity and processing.

The session on heavy metal halide glasses began with an invited talk reviewing the various potential glass compositions and their properties for use in fiber and bulk optical component applications in the 2–5 micron spectral region. A contributed paper described the synthesis, ultrapurification, and characterization of lanthanum fluoride, an important raw material for ultralow-loss fibers. Another paper discussed the importance of both the temperature dependence of viscosity and crystallization of heavy metal fluoride glasses in determining suitable processing conditions. Two papers described impurity analysis of such glasses. The first described a selectively excited photoluminescent technique that allows low part-per-billion determination of deleterious impurities in heavy metal halide glasses. The second paper reported on the use of EPR and optical spectra characterization to analyze transition metals in such glasses. The last paper in the session correlated the effect of sodium fluoride additions in fluorozirconate glasses to their resultant attack by liquid and gaseous water.

The session on nonsilicate lightguide materials began with an invited paper which discussed the various material systems and issues for transmission in the UV and far IR region of the spectrum, a region particularly important for optical power transmission. Contributed papers reported on: effects on the vibrational spectra of zirconium fluoride glasses deliberately doped with oxide species; investigation of the hydrogen bonding on the surface of wet beryllium fluoride glass using infrared absorbence; impact of tellurium additions for selenium on the optical and mechanical properties of arsenic tellurium selenide glasses; and the strength of antimony-germanium-selenium chalcogenide glass fibers.

The final session of the symposium focused on defects in silica-based fibers. An invited paper examined the role of either fiber drawing or photon-induced defects on the resultant optical spectra, and proposed possible mechanisms which explain the formation of various defect species. Three other contributed papers reported on specific studies which further elucidated the nature of defects in silica-based fibers. In one study ESR active species were correlated to specific processing variations, while in a second paper drawing

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conditions were varied along with composition, and the resultant radiation sensitivity and photoluminesce examined. In the final paper of this session, *in situ* hydrogen treatments of pure silica core optical fibers were used to profile defect formation and reactions.

Symposium Support: EM Chemicals, Office of Naval Research, AT&T Bell Laboratories, Corning Glass Works
Proceedings: Volume 88 of the Materials Research Society Symposium Proceedings series

Materials for Infrared Detectors and Sources (Symposium R)

Symposium Organizers: J.F. Schetzina (North Carolina State University), J.T. Cheung (Rockwell International), R.F.C. Farrow (IBM Almaden Research Center)

Symposium R Organizers (left to right): J.T. Cheung, J.F. Schetzina, and R.F.C. Farrow.

This symposium brought together the leading groups from the United States and Europe working on the preparation and characterization of materials for infrared detectors and sources. Much of the activity in this field is driven by the need for focal-plane array imagers operating in the medium (3–5 micron) and long (8–14 micron) wavelength atmospheric transmission windows. Such imagers can generate high spatial resolution, real-time video images of night scenes with the contrast provided by temperature differences in the scene. The military applications of such thermal imagers are far ranging. However, there are nonmilitary applications which include medical thermography and environmental monitoring. In addition there is a growing interest in the preparation and exploration of detector and source materials for fiber-optic communications at wavelengths beyond 1.5 microns.

The objectives of the symposium were threefold: (1) to review progress in the key areas of bulk and epitaxial growth technologies for preparing infrared materials; (2) to review techniques for characterizing infrared materials; (3) to evaluate the potential of novel materials and structures for infrared detectors structures. The symposium included 20 invited talks and 45 contributed talks extending over five days to allow generous time for discussions and in-depth overviews.

A one-day joint session with Symposium Q (Diluted Magnetic [Semimagnetic] Semiconductors) was held to deal with common approaches in preparing and characterizing materials.

The opening session of the symposium was on group III-V semiconductor-based infrared materials. These materials provide the present generation of optoelectronic devices for the near infrared spectral region. Furthermore, the degree of control over the structural, optical, and electrical properties of these materials presently far exceeds that achieved with alloys used in the medium and long wavelength regions of the infrared spectrum.

M. Panish (AT&T Bell Laboratories) reviewed the status of epitaxy of III-V compounds and alloys and pointed out that lattice-matched heterostructures with low defect density could now be routinely tailored to a precision of about a monolayer using molecular beam epitaxy (MBE), metal-organic chemical vapor deposition (MOCVD), and hybrid growth techniques (MOMBE). This degree of control has recently accessed several novel, GaAs-AlGaAs quantum well structures which exhibit narrow-band, long wavelength (10 micron) photoconductive response through field-assisted intraband transitions. The quantum efficiency of the initial devices was 6 % at 80 K but could probably be increased to near unity by adjustments to the device architecture. This approach clearly shows promise for detectors suitable for long wavelength fiber optic communications. It also demonstrates how complex, carefully designed structures can be realized which extend the spectral response of III-V semiconductors far beyond the cutoff wavelength limit set by the energy gap. This approach contrasts with that pursued by most groups to date: namely, the preparation of simpler, conventional detector structures in narrow-gap alloys, such as HgCdTe, where the problems are in controlling the material properties rather than in the growth of complex structures. An exception is HgTe-CdTe superlattices, where such structures offer potential advantages over the random alloy. T.C. McGill (California Institute of Technology) reviewed this field thoroughly and concluded that the measured properties of the superlattices were in agreement with theory but the band offsets were uncertain and contentious.

The performance of an infrared imaging system depends on the structural, optical, and electrical quality of the material forming the detector array, as well as the nature of the detector structure itself. This array is situated at the focal plane of the infrared optics and converts the thermal image into the electrical and, subsequently, video images. M. Kinch (Texas Instruments Inc.) reviewed the materials requirements for the detector material and pointed out the very tight specifications on carrier concentration and lifetime, as well as dislocation density, set by device physics and the need for background limited performance. The combination of these requirements, combined with technological factors in array production, led to the choice of HgCdTe as the preferred detector material.

The next generation of imaging systems will incorporate signal processing on the focal plane, either by charge transfer in the detector array itself or by interfacing the array to a silicon charge coupled device chip. Currently the material requirements for these systems have been met by only a limited amount of bulk material. As a result there is a push toward detector structures, such as heterojunctions, which allow relaxation of some materials specifications. These structures in turn require the development of epitaxial technologies which are capable of low growth temperatures (to avoid interdiffusion) and which provide control over carrier concentration and alloy composition. Progress in several technologies was reported at the meeting. In MBE, excellent photovoltaic response data for MBE-grown p-n junctions was reported by J-P. Faurie (University of Chicago at

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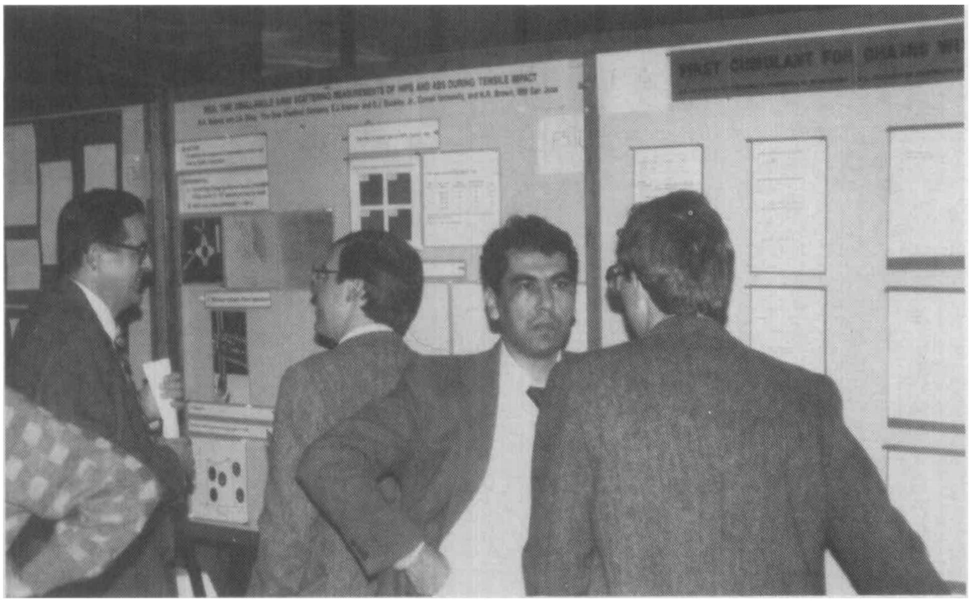

Poster Session.

Chicago Circle); T.H. Myers (General Electric Electronics Laboratory) and co-workers at N.C. State University reported Auger-limited, minority carrier lifetimes in excess of 3 microseconds for n-type, MBE-grown $Hg_{1-x}Cd_xTe$ alloy films with x = 0.21. In MOCVD, photo-assisted epitaxy of HgCdTe at 250°C with suppressed vapor nucleation was achieved by S.J.C. Irvine (Royal Signals and Radar Establishment, UK). Laser evaporation in UHV (J.T. Cheung, Rockwell International Science Center), of HgTe and CdTe sources, permitted arbitrary composition profiles to be prepared by programming the repetition rate of the lasers.

A major development, impacting a long-standing problem in wide-gap II-VI compounds, was reported by R.N. Bicknell (North Carolina State University, student award winner) in the joint session (with Symposium Q) on Infrared Materials/Dilute Magnetic Semiconductors. Controlled substitutional doping of CdTe was achieved by laser illumination of the film surface during MBE growth. In the absence of illumination the n-type (In) and p-type (Sb) dopants were chemically incorporated but were not on substitutional sites. With illumination, free carrier concentrations up to $10^{17}cm^{-3}$ were measured. This corresponded to 100% activation. The mechanism is contentious but the effect is reproducible and has accessed thin film p-n junctions for the first time. This may eventually enable II-VI diode light-emitting devices to be made.

In the area of characterization the complementary nature of techniques such as x-ray diffraction and transmission electron diffraction was well illustrated by invited reviews from W.J. Takei (Westinghouse R&D Center) and F.A. Ponce (Xerox PARC), respectively. Contributed papers highlighted the equal importance of electrical and optical probes of infrared materials.

Although most of the papers in the symposium were on detector materials, the subject of materials for infrared sources was not ignored. D.L. Partin (General Motors Research Laboratories) reviewed the range of IV-VI diode lasers which could now be prepared and operated in the CW mode in the wavelength range from 2 to 8 microns. These have applications ranging from trace gas detection and pollution monitoring to fiber optic communications.

The symposium was well attended and achieved its objectives. In particular, it provided a much needed forum for wide-ranging discussions on all the important infrared materials currently under development.

Symposium Support: IBM Corporation, Air Force Office of Scientific Research, Army Research Office, Office of Naval Research, DARPA

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Superconducting Materials (Symposium S)

Symposium Organizers: J. Bevk (AT&T Bell Laboratories), A.I. Braginski (Westinghouse Research and Development Center)

This year's symposium, the second MRS symposium on this subject, featured a narrowly defined topical program emphasizing superconducting thin films and epitaxial film structures, tunneling barriers, and superconducting effects occuring in multilayers and near film interfaces with semiconductors, normal conductors, and magnetic insulators. Low carrier density superconductors and unusual resistivity and critical temperature results, possibly indicative of interface superconductivity mechanisms, were also included in the program. These directions of research are among those most actively pursued during the last few years. In addition to reporting specific results, the program was formulated to provide a forum for freely discussing current problems and challenges. The symposium was accordingly structured around a large number of invited talks with ample time for discussions. A significant fraction of invited talks (over 40%) were presented by international (especially Japanese) speakers. The Japanese participation was largely due to the efforts of M. Igarashi (NTT Electrical Communications Laboratories, Japan), a member of the symposium advisory committee.

Attended by over 100 participants, the symposium maintained a high level of interest and heated discussion through the last session. The major highlight of the symposium discussions was an unscheduled announcement by K. Kitazawa (Tokyo University). Following the recent results by IBM-Zurich researchers (J.G. Bednorz and K.A. Mueller, *Z. Phys.* **B64**, 1986 p. 198) the Tokyo University researchers found some credible evidence of a new low-carrier-density superconductor, barium-lanthanum-copper oxide, having an onset of superconductivity at 30–35 K. The superconducting phase (which is oxygen-deficient) is thought to be perovskite-like and related to the K_2NiF_4 structure.* Other highlights of the symposium included progress in understanding of superconductor/semiconductor interfaces and problems intrinsic to the superconducting FET (A.W. Kleinsasser, IBM Yorktown Heights), unusual proximity effects in heavy fermion/niobium layered structures (L.H. Greene, BELLCORE), and the successful formation of epitaxial layered

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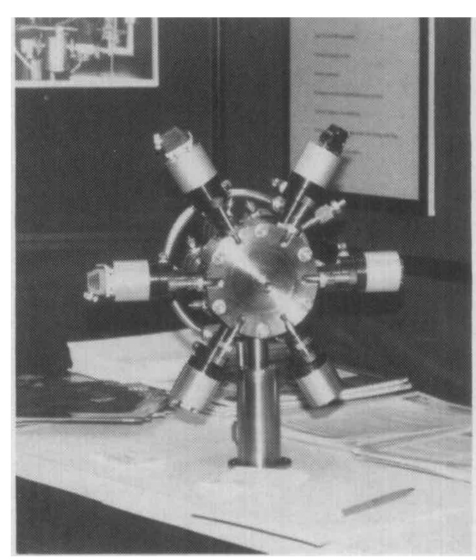

Equipment Exhibit.

Symposium S Organizers (left to right): J. Bevk and A.I. Braginski.

tunneling structures of NbN and MgO which were reported by several speakers. Epitaxial and single crystal films of many high-critical-temperature superconductors have now been successfully grown and conditions for epitaxy analyzed (J. Talvacchio, Westinghouse R&D Center).

Symposium Support: Advanced Control Systems; AT&T Bell Laboratories; Fujitsu, Ltd.; Instruments S.A., Inc.; NEC Corporation; NTT Corporation; Office of Naval Research; Temescal; VG Instruments, Inc.; Varian Associates, Inc.; Westinghouse Electric Corporation
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***Editor's Note:** See "NSF Announces Discovery of New High Temperature Superconductor" in Research/Researchers in this issue. See also the description of Symposium S on High Temperature Superconductors with T_c over 30 K in "Preview: 1987 MRS Spring Meeting" in this issue.

Fractal Aspects of Materials (Symposium U)

Symposium Organizers: D.W. Schaefer (Sandia National Laboratories), R.B. Laibowitz (IBM), B.B. Mandelbrot (IBM and Harvard University), S.H. Liu (Oak Ridge National Laboratory)

The concept of fractal geometry is emerging as a key simplifying concept necessary to understand the structure and properties of disordered materials. The symposium on Fractal Aspects of Materials reflected both the power and limitations of fractal concepts applied to materials.

The symposium was opened by T. Witten, who with his collaborators was responsible for the first observations and fractal models for colloidal aggregates. Witten analyzed some of the unique properties of tenuous objects. Recent studies of colloid aggregation were reported by T. Freltoft, A.J. Hurd, M.L. Broide, and D.S. Cannell. Although the basic properties of aggregates are captured by fractal models, several experimental observations remain unexplained.

The evening discussion associated with the symposium centered on the work of A. Le Mehaute, who developed a model for the response of fractal electrodes in batteries. P. Bro noted the similarity of electrochemical problems with other phenomena and also emphasized the economic importance of electrode characterization.

Numerous studies of porous media were reported. Both J. Fripiat and P. Pfeifer developed theories for multilayer absorption on fractal surfaces. Although both concluded that monolayer absorption can reveal fractal surfaces, issues such as energetic disorder and geometric bottlenecks can compromise interpretation of experimental data. D. Avnir and P. Schmidt emphasized the fractal interpretation of absorption experiments, whereas M. Drake reported energy transfer experiments on silica which are consistent with classical smooth surface porosity.

Both J. Martin and L. Leibler reported studies of polymer gelation. Although certain aspects of both studies were consistent with percolation, both speakers felt that the nature of the sol-gel transition is still in question.

The symposium included several papers on nonfractal disordered materials. D. Nelson discussed the folded sheet materials, as well as the concept of frustration. S. Nagel reported dynamic studies of the glass transition. Finally, M. Glicksman and J. Langer analyzed the structure and essential physics of dendritic pattern selection.

Next year's symposium will be organized by Alan Hurd, David Weitz, and Benoit Mandelbrot. Suggestions should be directed to Alan Hurd; telephone (505) 846-3704.

Symposium Support: Office of Naval Research, IBM Research Center
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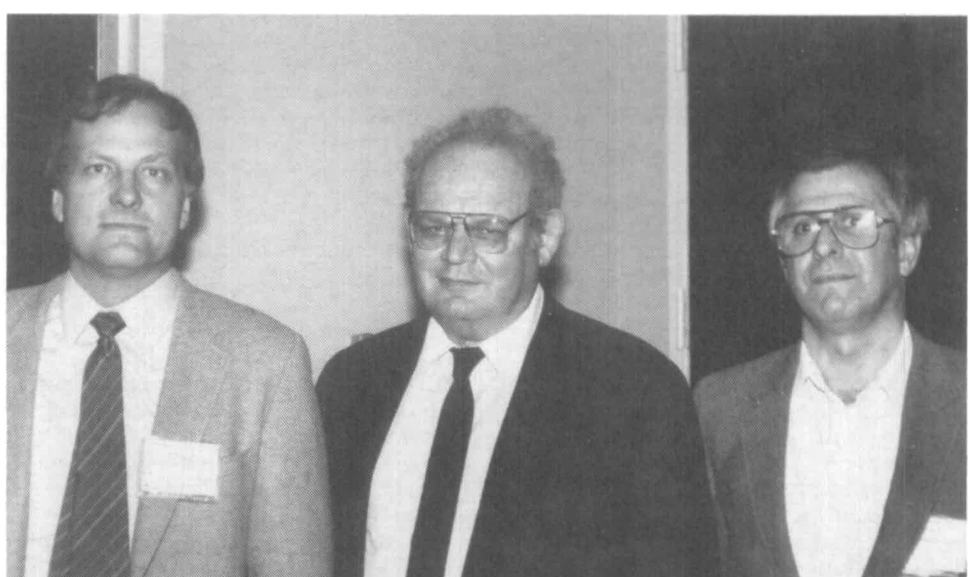

Symposium U Organizers (left to right): D.W. Schaefer, B.B. Mandelbrot, R.B. Laibowitz. (Not shown, S.H. Liu)

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