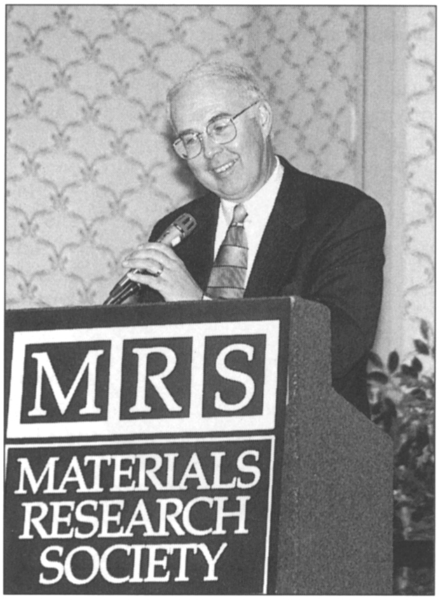
1995 MRS Fall Meeting Assembles in Boston

The 1995 MRS Fall Meeting assembled 34 symposia with over 4,000 oral and poster presentations into the Boston Marriott Hotel and Westin Hotel/Copley Place and the Sheraton Boston Hotel November 27–December 1. The meeting, chaired by Michael J. Aziz (Harvard University), Berend T. Jonker (Naval Research Laboratory), and Leslie J. Struble (University of Illinois at Urbana-Champaign), reflected the diversity of the field, spanning topics ranging from thin films for biomedical applications and the electrical, optical, or magnetic properties of organic solids, to cement and nuclear waste management, gallium nitride, and emission from diamond. A new tutorial program debuted at this meeting, which integrated half- and full-day tutorials into the technical program to give the audience in-depth reviews of areas such as *in situ* electron microscopy, electron emission from diamond, properties of organic solids, fracture, epitaxial metal oxides, and silicides for integrated circuits.

The First International Symposium on Gallium Nitride and Related Materials, held as Symposium AAA, provided a forum for pioneers and leaders in the field of blue/green light emission. An audience heard presentations on device accomplishments including the fabrication of bright and efficient LEDs, and searched for an understanding of materials principles to advance device performance in this field. CREE Research presented results of high-brightness GaN/SiC blue LEDs, and Nichia Chemical Industries, Ltd. reported the development of high luminosity LEDs in yellow, green, and blue. Beyond understanding and controlling the microstructure and defect networks of these materials, technologists strive toward developing GaN-based laser structures.

In Symposium S, Covalent Ceramics III—Science and Technology of Non-Oxides, approaches to processing epitaxial thin films of GaN were presented including a discussion of concepts underlying the mechanism of nucleation of misfit dislocations and new approaches to lower the density of threading dislocations in lattice mismatched layers.

The most intensively discussed application in Symposium DD, Diamond for Electronic Applications, was diamond as an electron emitter, due to the negative electron affinity of some diamond surfaces. Diamond, diamondlike carbon, and other wide bandgap semiconductors are being considered for flat-panel displays, pressure and gas sensors, switches, amplifiers, and radiation detectors. Diamond containing boron becomes a semiconductor and exhibits piezoresistance (change of electrical resistance with strain), so it can be used as a strain gauge on rugged electronic microsensors for pressure and acceleration sensing, even at high temperatures. Diamonds can also be used as chemical sensors of hydrogen, oxygen, and other materials.



Rep. Robert S. Walker, chair of the Committee on Science in the U.S. House of Representatives, gives the plenary presentation on "Why U.S. Policies Affecting Science are Changing."

In Symposium EE, Optoelectronic Materials—Ordering, Composition Modulation, and Self-Assembled Structures, one achievement reported was the growth of quantum wire lasers by strain-induced lateral-layer ordering using single-step molecular-beam epitaxy. The lasers showed an orientation-dependent threshold current density and lasing spectra and an unprecedented lasing wavelength stability of less than 0.9 Å/°C. The growth mechanism allows wires to be formed without pre-growth substrate patterning or post-growth processing. Two laser wavelengths were reported, 1.7 μm and 0.7 μm, both of which are important to the communications industry.

Organic materials are emerging as promising candidates for future electronic, optical, and magnetic devices, as described in Symposium W. Conducting polymers, which offer the benefit of easy processing, low cost, and mechanical flexibility, have been fabricated into LEDs, batteries, and other devices, and have gained reasonable performance characteristics when combined with other polymers. However, to achieve broader success and to take full advantage of the assets of this technology, packaging methods are needed that keep deleterious oxygen and water out, and allow the conducting polymers to flex. Poled guest-host chromophore-polymer designs with various combinations of functionalization, cross linking, and other structures were discussed for second order nonlinear optics.

In Symposium A, the results of a Department of Energy panel study on energetic ion beams in semiconductor processing were reviewed. This study provided guidelines for using ion implantation in the competitive world of microelectronics in the next 10 years. New paths in the implantation arena include the production of nanocrystals and quantum dots in insulators for nonlinear optical properties and photoluminescence, and use of a plasma source as a potentially more versatile technique than traditional implantation since it can treat large, irregularly shaped surfaces.

New diagnostic equipment and processing techniques extend the horizons of materials research and represent an expanding sector of the materials community. *In situ* electron and scanning tunneling microscopy studies (Symposium J) have made possible the observation of dynamic reactions, including gas-solid dynamics, chemical etching, deposition processes, homoepitaxy, and electromigration. Optical techniques in particular have emerged to meet the semiconductor industry's need for rapid, accurate diagnostic techniques both *in situ* and *ex situ*. Diagnostic techniques addressed in Symposium L included optical emission spectroscopy, reflectance spectroscopy, and laser light scattering for monitoring growth in molecular-beam epitaxy (MBE) and chemical vapor deposition (CVD) systems. Proximal probe techniques such as scanning tunneling microscopy (STM), atomic force microscopy (AFM), and near-field scanning optical microscopy (NSOM) were shown to successfully address problems in materials processing and nanoscale lithography. Demonstra-

https://doi.org/10.1557/S0883769400036174 Published online by Cambridge University Press

Award Recipients Represent a Range of Materials Research

Recipients of the Von Hippel Award, the MRS Medals, the Turnbull Lectureship, and the Graduate Student Awards were honored Wednesday evening during the awards ceremony. Profiles of the award recipients were published in the November 1995 *MRS Bulletin* and transcripts of some of their presentations will appear in future issues of the *Bulletin*.

Following the awards ceremony, William W. Mullins (Carnegie-Mellon University), who received MRS's highest honor, the Von Hippel Award, gave a presentation on the evolution of materials science. He said that microstructure is at the heart of materials science. Trends he has observed in the field include progression toward smaller scales, phases farther from equilibrium, topical diversity, and computer modeling. As examples, he cited laser-ablated oxide superconductors, fullerenes, quasicrystals, Ni-based superalloys, dynamics of silicon steps, structural color of opals, tunnel diodes with barriers that are only a nanometer across, and a sea urchin spine made of single-crystal calcite. He then turned to microstructural evolution and capillarity, which is important for small-scale objects, in analogy to flies walking on the ceiling and waterbugs walking on water. He applied these concepts to soap bubbles and grains. Looking toward the future, Mullins envisioned bridging the gap between thermodynamics and atomistics, equilibrium and kinetic effects, and computer modeling and experiments.

As part of Symposium P, Didier de Fontaine, the 1995 MRS Turnbull Lecturer and professor of materials science and engineering at the University of California—Berkeley, related electronic structure to phase structure for the purpose of developing alloy phase equilibria diagrams. He gave recent examples of how combined advances in electronic structure and cluster methods made possible reliable nonempirical investigations of alloy phase equilibria. He described the progression through the Bragg-Williams approach, the mean-field approach, the cluster variation model, and cluster expansion, then to *ab initio* calculations.

MRS Medalist R.M. Tromp, manager of Interface Science at the IBM T.J. Watson Research Center, presented his award lecture on surfactant-mediated epitaxy of Ge on Si and Si(001) homoepitaxial growth, as part of Symposium J, *In Situ* Electron and Tunneling Microscopy of Dynamic Processes. He described how a surfactant placed between layers of two materials that do not smoothly layer reduces the surface free energies of both materials and inhibits islanding. For homoepitaxy, he found that step fluctuations are limited by attachment and detachment, there are strong nearest neighbor correlations leading to Ostwald ripening, two-dimensional nucleation required large critical nuclei, and the system is close to thermodynamic equilibrium. Because of the high energy associated with the surface, he showed that it is energetically favorable for the atoms to accumulate to form a straight step edge.

MRS Medalist Federico Capasso, head of the Quantum Phenomena and Device Research Department at AT&T Bell Laboratories, gave his award lecture in Symposium CC, Spectroscopy of Heterojunctions. He described artificially structured semiconductors such as the quantum cascade laser, which uses quantized states in the conduction band instead of electron-valence band hole recombination. It has "atomic-like" transitions between conduction band quantum-well energy levels and sequential photoemission in a high electric field. Wavelengths span from 4.3 to 5.26 μm and 7.8 to 11 μm. Operation of a continuous wave laser at 100 K can produce 2 mW at a wavelength of 5.1 μm and at 77 K can produce 17 mW at a wavelength of 7.8 μm. Pulsed operation of 3 mW has been achieved for 5.2-μm-wavelength emission at room temperature. This technology is enabled by having spatial control of the composition and doping down to the atomic scale. This makes it possible to tailor the band structure and wave functions arbitrarily and to continuously produce tunable electronic and optical properties for new devices.

Ten Graduate Student Awards Presented at the 1995 MRS Fall Meeting

As a result of special talk sessions which were held during the 1995 MRS Fall Meeting in Boston, 10 students received Graduate Student Awards. All 30 finalists (see *MRS Bulletin, November 1995, p. 94*) received recognition at the Awards session, and 1995 MRS President Julia M. Phillips presented a plaque and a cash award of $250 to each of the recipients. The awards are intended to honor and encourage graduate students whose academic achievements and current materials research display a high degree of excellence and distinction.

Graduate Student Award Recipients at the 1995 MRS Fall Meeting.

(Seated, left to right) Yongwu Yang (Massachusetts Institute of Technology), Sridhar Narayanaswamy (University of Michigan), Sundar Ramamurthy (University of Minnesota), and Patrick Tepesch (Massachusetts Institute of Technology).

(Standing, left to right) Paul G. Sanders (Northwestern University), Ellad B. Tadmor (Brown University), Daniel W. Pack (California Institute of Technology), Nora V. Edwards (North Carolina State University), Yong Chen (University of California—Berkeley), and Scott A. Walker (University of California—Santa Barbara).

https://doi.org/10.1557/S0883769400036174 Published online by Cambridge University Press

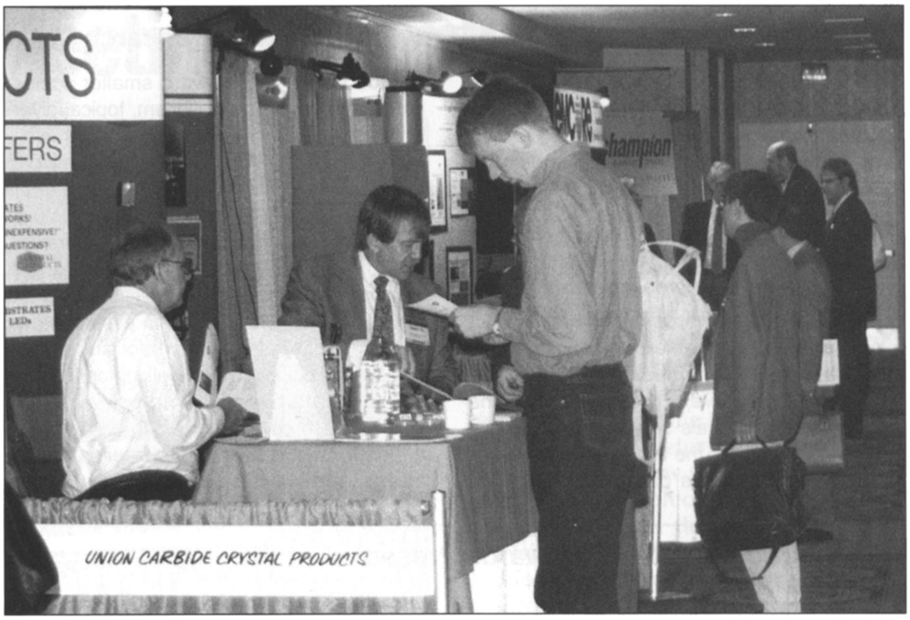
tion of the extension of dynamic light scattering techniques using x-ray photon correlation spectroscopy has opened the possibility of probing dynamics (e.g., of gold colloids) on length scales of interatomic spacings.

The application of electrical measurements for the detection of microstructural features at all length scales (atomic to macroscopic) was the subject of Symposium T, Electrically Based Microstructural Characterization. Of note were papers covering new applications of impedance spectroscopy to ferromagnetic materials and resolving microstructural features on a local level. Chemical heterogeneities and physical defects have been studied in organic coatings used to protect metals against corrosion. Defects were also studied in II-VI compounds and ferroelectrics, solder flux, very largescale integration (VLSI) interconnects undergoing electromigration, and composites.

The nature and role of crystal defects and their influence on the critical current density J_c was an underlying theme of Symposium F on high T_c superconductor research. Grain-boundary junctions and semiconducting quantum interference devices (SQUIDs) have been made with Hg-based superconductors. Although these materials superconduct above 160 K and have high J_c (up to 10^6 A/cm^2), they are difficult to synthesize, lose mercury at low temperature, and cannot be textured. In another class of materials, a T_c of 124 K was reported for high-pressure-synthesized samples in the Cu-Ba-Ca-Cu-O system, which—if verified—would be a record for a material without a toxic element such as Hg.

In Symposium D, Evolution of Epitaxial Structure and Morphology, STM studies revealed unusual behavior of metal atoms on surfaces. When immiscible materials are placed on a surface with significant lattice mismatch, the two materials migrate and combine in an energetically favorable way to relieve the strain on the surface, thus forming a two-dimensional alloy film. For instance, when Ag and Co are put on a Ru surface, Ag atoms collect around the border of Co islands or form a dendritic structure at room temperature with a striped phase in the dendritic arms consisting of a distinct combination of Co and Ag, with Ag collecting along steps. The amount of strain in the film is crucial in determining whether the interface between the materials is smooth or rough.

Biological systems in nature provided both a model and a starting point for devising novel materials, as described in Symposium U, Materials Inspired by Biology. Nanostructural design can be accomplished through the self-assembly of organics followed by structural organization of the inorganics through catalytic or epitaxial growth on the organic surfaces. Nanoscale structures can be formed through self-assembly, molecular recognition and scaffolding, and by pattern development through chemical reactions with the aid of applied fields.



The exhibitors' booths, traditionally showcased in the Boston Marriott Hotel and Westin Hotel/Copley Place, expanded into the Sheraton Boston Hotel.

Symposium Z on thin films and surfaces for bioactivity and biomedical applications emphasized methods of thin-film preparation and surface modification and *in vitro* experiments designed to assess biological responses to surfaces with the goal of creating and modifying surfaces that would elicit specific biological responses. Fabrication of surfaces that resist adsorption of proteins and adhesion of cells is one step toward avoiding nonspecific surface interactions. Examples were presented of surfaces produced by RF-plasma deposition and molecular self-assembly of alkane thiols and DNA nucleotide bases.

Self-assembling materials and structures (Symposium O) are built from the bottom up, based on structures which form spontaneously due to intermolecular forces that dictate the form or pattern of the final structure. Self-assembled monolayer films are being fabricated by photochemical, electron beam, or contact printing techniques for use in electronics, sensors, and optical applications. Phospholipid tubules were demonstrated as vehicles for controlled release drug delivery. Micron- to submicron-sized arrays have been developed as substitutes for gel electrophoresis to fractionate DNA (to separate such objects as cells and high-molecular-weight DNA); the fractionation process can be directly imaged by video microscopy.

Symposium N on Complex Fluids covered foams, biopolymers, emulsions, colloids, and liquid crystals. In most cells the cytoskeletal rim, consisting mostly of actin filaments, provides mechanical stability and plays a key role in cell motion. Such protein filament networks *in vitro* also provide novel systems for the study of polymer solutions and gels. Both macroscopic rheological measurements and direct video imaging of the dynamics of individual filaments were reported. Cytoskeletal protein networks and gels can be used as models for the study of basic polymer science.

Symposium Y, Long-Term Performance Issues in Polymers—Chemistry and Physics, covered prediction of in-service performance of plastics and coatings, residual stresses and the dimensional stability of injection molded thermoplastic parts. The physical aging of polymers and its relationship to polymer longevity were also discussed.

A pervasive theme of Symposium P, Materials Theory, Simulations, and Parallel Algorithms, was the increasing success of efforts to join atomic-level calculations with large-scale approaches. For example, the progression of a crack tip in copper now can be modeled using simulations with over three million atoms (showing dislocations emanating from the fracture), and these techniques complement macroscopic simulations and experimental analysis. Massively parallel computer molecular dynamics simulation techniques can even model the evolution of 10^6 to 10^8 atoms.

Dismantlement of thousands of Russian and U.S. nuclear weapons and related activities will produce more than 100 tons of excess weapons grade plutonium by the year 2003. The danger of weapons proliferation and unintentional criticality, as well as radioactivity, require careful control and dispositioning of this material. Two recommendations from the Committee on International Security and Arms Control of the National Academy of Sciences were presented by R.L. Garwin in Symposium V, Scientific Basis for Nuclear Waste Management XIX. The first recommendation—based on security, legality, practicality, and economy—is to mix excess plutonium in borosilicate glass logs, designed for disposal of fission products generated during original plutonium production, for permanent disposal in a mined geologic repository. The second recommendation is to mix plutonium with depleted uranium to produce mixed oxide ceramic fuel for use in power-generating nuclear reactors.

A heavy emphasis of Symposium R, Mechanisms of Chemical Degradation of Cement-Based Systems, was the relationship between microstructure and chemical degradation. In particular, papers discussed the transport of aggressive ions such as chloride (steel corrosion), sulfate (sulfate attack), hydroxide (alkali silica reaction), and carbonate (carbonation) in limiting the rate of chemical attack. Several papers dealt with computer modeling of these processes and the prediction of the performance of concrete barrier systems for low-level radioactive waste depositories. Also, scientists have been reexamining the chemical processes underlying sulfate attack and the stability of sulfate-containing phases. A major lawsuit involving the cracking of concrete railroad ties supplied to Amtrak prompted increased research in the area of delayed ettringite formation.

Three challenges for successful manufacturing are achieving low cost, short time to market, and high quality. "Cost" is a term that is increasingly creeping into the vocabulary of materials researchers as relevance to commercial success becomes a concern. Symposium AA, Low-Cost Manufacturing of Materials, presented some of the constraints and opportunities for research involving materials. Target-costing involves setting the cost for a product, and backing out the costs for earlier steps in the process for materials and processing. As an example of how materials selection affects processing costs, one researcher reduced the cost of a washing machine by 15% by switching from enameled steel to talc-filled polypropylene, because the new material could be more easily molded and assembled.

For further details about the technical content of the meeting read the following symposium summaries and see the published proceedings.

Plenary Presentation and Panel Discussion Address Science Policy

To help MRS members understand the effect on materials research of heavy budget cut proposals in the U.S. government, organizers of the 1995 MRS Fall Meeting invited Rep. Robert S. Walker, chair of the Committee on Science in the U.S. House of Representatives, to give the plenary talk Monday evening (see *MRS Bulletin*, February 1996, p. 3, for Walker's edited transcript). His talk was followed by a panel discussion Tuesday morning on the changing character of science policy, moderated by D. Allan Bromley who was Assistant to the President for Science and Technology during the Bush administration in the late 1980s to early 1990s. Bromley and the Bush administration triggered a presidential initiative on materials science and synthesis* after a National Research Council (NRC) report**—co-chaired by Praveen Chaudhari—showed how the United States was falling behind its international competitors in those areas.

Walker, Bromley—Dean of Engineering at Yale University—and the two panelists, Chaudhari of IBM Research and Graham Mitchell, assistant secretary for technology policy at the U.S. Department of Commerce, all agree that the U.S. government should support federal investment in long-term basic scientific research. They differ in their ideas of what role federal government should play in terms of global competition and the refocus of government missions; the murky area lies in what the government policy should be during the time between federal investment in basic research and private investment in product commercialization, as evident in the fate of the Advanced Technology Program (ATP).

Walker identified ATP as "corporate welfare" and supported zeroing it out. Bromley, under the Bush administration, had invented the program as a pilot study of how the federal government could effectively interact and cooperate with the private sector. Graham further emphasized the necessity of this type of program to bridge the gap between basic research and commercialization. "From an industry perspective, the funding issue and availability of resources for new technology are closely linked to perceived uncertainty and risk," he said. Businesses will typically refrain from major investments until the risks have been adequately reduced. Chaudhari's talk supported this view. R&D is only a part of a company's strategy to bring out a product and market it; the rest of the strategy is to search outside for knowledge to bring into the organization. He said, "It's far more effective for a company to go and get that knowledge, acquire that company, absorb it and get the product out on the market much faster than a competitor would, rather than for them to do research, development, and then manufacturing."

* *Advanced Materials and Processing: The Fiscal Year 1993 Program* (FCCSET Committee on Industry and Technology, 1992); see *MRS Bulletin* **XVII** (3) (1992) p. 18.

** *Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials* (National Academy Press, Washington D.C., 1989); see *MRS Bulletin* **XIV** (10) (1989) p. 27.

Guidelines Presented for Future of Ion Implantation

(See MRS Proceedings Volume 396)

Symposium A, Ion-Solid Interactions for Materials Modification and Processing, set the guidelines for the fundamentals of ion-beam processing of materials on several areas such as ion-beam mixing, ion-beam modification of polymers and photorefractive materials for photonics and electronics applications, ion-beam processing of surfaces, as well as on new applications in semiconductor device fabrication. An extensive coverage of the application of ion beams for the formation of embedded thin films, nanocrystals, quantum dots in insulators for photonic application, and device fabrication had an audience of over two hundred people and was followed by a well-attended poster presentation. A special session on focused ion beam preceded an invited talk on Thursday morning by S. T. Picraux (SNL) which provided a guideline for using ion implantation in the competitive world of microelectronics during the next 10 years. Picraux provided input on the trend toward smaller dimensions in IC technology which presents the users of ion implantation techniques with serious physical and engineering challenges. He also reviewed the results of a Department of Energy Council on Materials Panel Study that was held to discuss the current status and future opportunities for ion beams in semiconductor processing. The focus

https://doi.org/10.1557/S0883769400036174 Published online by Cambridge University Press

areas discussed included modeling of defects and dopant distributions; transient enhanced diffusion; high-energy implantation; and damage, gettering, and surface modification. Advances in accelerators and analytical requirements for high-resolution profiling and contamination-free manufacturing were also discussed.

Other sessions emphasized the significant role of ion-beam processing of materials in photonic device fabrication by producing embedded nanostructures such as quantum dots in photorefractive materials as well as the fabrication of specialized gratings in polymers used in photonic industries.

Symposium Support: Nat'l Electrostatics Corp.; Alabama A&M Univ., Center for Irradiation of Materials; GM.

Right: D. Allan Bromley, Dean of Engineering at Yale University and former Assistant to the President for Science and Technology, moderated a panel discussion on the changing character of science policy.

Left: Graham Mitchell, assistant secretary for technology policy at the U.S. Department of Commerce and one of the panelists for the Forum on The Changing Character of Science Policy, discusses the necessity for the federal government to bridge the financial gap between basic research and commercialization.

Laser Ablation Applied in Materials Processing

(See MRS Proceedings Volume 397)

Symposium B, Advanced Laser Processing of Materials—Fundamentals and Applications, focused on emerging applications of lasers in materials processing. Many of the discussions centered around the understanding and application of pulsed-laser ablation. D. Geohegan (ORNL) spoke about fast spectroscopic imaging of the ablation plume using gated, species-resolved intensified charge-coupled device (ICCD) photography. He showed that the ablation plume transport can involve multiple plume components having significantly different chemical and excitation characteristics. The specific case of carbon ablation in forming sp^3-bonded amorphous film deposition was treated in detail. He also presented evidence for cluster formation in the plume when ablating into a background gas.

Cluster formation was the subject of several other talks, including a presentation by W. Marine (Laboratoire Interdisciplinaire Ablation Laser et Applications, CNRS) on the formation of Si nanocluster films by laser ablation. Using optical emission, time-of-flight spectroscopy, and ICCD-imaging, he was able to correlate the characteristics of the ablation plume with Si_2 and $SnSiO_2$ nanocluster film photoluminescence spectra.

The use of laser ablation in depositing diamondlike carbon (DLC) films included innovative choices for ablation targets. M. Hanabusa (Toyohashi Univ. of Technology discussed the use of frozen source gases as ablation targets by condensing acetylene on a liquid nitrogen cold finger. R-F. Xiao (Hong Kong Univ. of Science and Technology) described the use of low-vapor-pressure organic-liquid ablation sources in forming DLC films by laser ablation. The physics and chemistry of laser/solid interaction using both pulsed- and cw-lasers were discussed, with E. Mazur (Harvard Univ.) presenting an overview of laser/solid interactions involving femtosecond laser pulses, while D. Bauerle (Johannes-Kepler-Universität—Linz) reviewed the influence of instabilities on specific structure formation in cw-laser chemical vapor deposition (CVD).

Symposium Support: Thermionics Inc.

Insight Gained Through Quantitative Analysis of Phase Transformation Kinetics

(See MRS Proceedings Volume 398)

Symposium C, Thermodynamics and Kinetics of Phase Transformations, reflected the continuing interest in and the central importance of phase transformations in materials science. The emphasis throughout was on the quantitative analysis of transformation kinetics, integrated with thermodynamics.

Solidification remains a success story for quantitative kinetic analysis. The experimental work reported concentrated on phase selection under extreme processing—large undercooling or ultrarapid quenching—of the liquid. New theoretical treatments were concerned mainly with the analysis of morphological instabilities during directional solidification at more conventional rates.

The coverage of particle-beam effects was distinguished by the wide range of materials studied: alkali halides, minerals, semiconductors, and metals.

The thermodynamics of and reactions at interfaces were a particular focus, especially in connection with the solid-state formation of amorphous phases. With amorphous alloys, the main interest was on new, bulk glass-forming compositions—whose stability permits thorough thermodynamic and kinetic studies of a kind not possible before.

An appropriate highlight for the symposium was the coverage of the Johnson-Mehl-Avrami-Kolmogorov analysis of overall transformation kinetics. This venerable treatment was revisited and new insights and limitations were explored. The presentations on nucleation illustrated the simultaneous progress on experimental observation and theoretical analysis.

Morphology of Epitaxial Films Explained Experimentally and Theoretically

(See MRS Proceedings Volume 399)

Symposium D, Evolution of Epitaxial Structure and Morphology, traditionally has focused on morphological issues pertinent to thin-film growth. This year, the organizers chose to concentrate attention on crystalline films grown epitaxially. Experimental review talks examined structure and morphology evolution as judged by x-ray and electron diffraction (RHEED) and, more so than in previous years, scanning tunneling microscopy (STM). Two STM presentations in particular—a variable temperature study of Rh/Rh(111) homoepitaxy that revealed re-entrant roughening and a study of GaSb/GaAs(001) heteroepitaxy from submonolayer to micron film thicknesses—left groups of people debating in the hallways long after the talks ended.

Theoretical review talks reviewed advances in the use of self-consistent rate equation modeling and Monte Carlo simulations. In favorable cases, these techniques agreed both with one another and with experiment on epitaxial island densities and island size distributions.

Presentations showed that experiment and theory agree that microscopic details—such as the magnitude of the energy barrier for an atom to descend over a step edge—controls the propensity for three-dimensional island formation during homoepitaxy. But the rate at which such structures coarsen as deposition continues is not well-understood. Similarly, the important role of island and facet nucleation (as opposed to morphological instability) and the mechanics of dislocation injection were the subject of considerable debate as elements crucial to strain relief in semiconductor heteroepitaxy. Other important elements that control structure and morphology such as the purposeful introduction of foreign species (surfactants) were found to recur throughout the symposium.

Symposium Support: Fisons Instruments, LK Technologies, Granville Phillips Co., k-Space Assoc., Digital Instruments, JEOL, Univ. Of Michigan, Canim Scientific, ORNL.

Molecular Dynamics Simulations Elucidate Behavior of Metastable Metallic Nanostructures

(See MRS Proceedings Volume 400)

Symposium E, Metastable Metal-Based Phases and Microstructures, was held for the first time, and included over 100 papers. P. Bellon (CE Saclay, France) led off the symposium with a stimulating discussion of how steady-states, which are thermodynamically unstable, develop in driven systems. These ideas were illustrated in a poster on mechanical alloying of immiscible systems by T. Klassen et al. (Univ. of Illinois at Urbana-Champaign), who found the co-existence of three phases in the binary system, Cu/Ag. The growing importance of computer simulations in this field was a second echoing theme of the symposium. With the growing capabilities of advanced computers and decreasing size of the microstructural units in metastable systems, molecular dynamics has become a practical means to treat very difficult problems. D. Wolf and co-workers (ANL) used MD to elucidate the thermodynamic properties of nanocrystalline materials, while G. D'Agostino (ENEA Innovation Dep., Italy) and H. Van Swygenhoven (Paul-Scherrer-Institute) used MD to simulate tensile deformation in a nanocrystalline sample containing over 10^6 atoms (50 grains). Several papers in the symposium reported on metastable systems that are finding their way into the market place. J. Parker (Nanophase Technologies Corp.) showed the net-shape forming ability of nanocrystalline TiO_2 for uv radiation absorption. R. Schulz (Hydro-Québec Research Institute) pointed out the huge energy and cost savings of using nanocrystalline Ti-R-Fe-O materials in the production of the paper bleaching agent, sodium chlorate, and he showed that the hydrogen charging times are significantly

Topics of General Interest Presented for the Nonspecialist

Symposium X, Frontiers of Materials Research, serves as a melting pot where materials researchers from diverse backgrounds receive general introductions to topics in areas other than their own. The talks were given at noon so as not to conflict with the morning and afternoon technical sessions. Topics at this meeting included forensics, radioactive waste disposal, doping of wide bandgap semiconductors, glass-ceramics, systems design of materials, and modeling from processing to performance.

As technological analysis of forensic evidence advances, court convictions decrease because the methods described by expert witnesses are too complicated for the average juror to understand. John A. Reffner of Spectra-Tech Inc. said that a juror "will translate this uncertainty into reasonable doubt." Reffner's graphic, detailed presentation of case histories defined the application of science and technology to matters of law. He described methods used to evaluate materials in forensic evaluations, including infrared microspectroscopy to characterize trace evidence; microbeam analysis using SEM-EDX to detect spherical particles containing barium, lead, and antimony from gunshot residues; and environmental, or E-SEM, for gunshot-residue analysis. In a forensic investigation, scientists are given a material whose history they must extract. For example, a scientist may need to examine a damaged car to determine all the forces that would have caused the damage, and then can trace whether the car had its headlights on during an impact by determining the heat factor and oxidation of a broken bulb. Reffner also gave several other examples.

Despite the recognized contributions of materials science to radioactive waste disposal, materials science has had only a limited impact on disposal strategies because the emphasis has been on geologic disposal rather than immobilization or containment. University of New Mexico professor Rodney C. Ewing presented the areas in which materials science can contribute to the safe isolation of radioactive waste, focusing the discussion on waste form, canister, and backfill materials. He followed the specific example of disposition of excess weapons plutonium. Comparison of crystalline ceramic phases including zircon, zirconolite, monazite, and apatite illustrates the methodology for evaluating and comparing different waste forms.

James Chadi (NEC) looked at II-VI wide bandgap semiconductors and the problem of self-compensation, which prevents full activation of dopants. He explained that the self-compensation occurs through a rearrangement of bonds in the vicinity of the impurity rather than from lattice defects. Off-center displacements and broken bonds expose atomic orbitals of the dopant impurities, and the impurity compares the energy of its orbital relative to the conduction or valence band edges. If energy differences to pay for the strain energy needed to break bonds are large, then large lattice relaxation occurs, which interferes with doping.

Gregory B. Olson of Northwestern University spoke about systems design of materials. The approach integrates processing, structure, property, and performance relations in the science-based conceptual design of new materials. He derived quantitative property objectives from property-performance plots. Combining principles of materials science, applied mechanics, and quantum physics, he provided mechanistic models for key structure/property and processing/structure relations. Then database and software systems are used to apply this information to suggest promising new alloys for a particular application.

Glass-ceramics are microcrystalline materials formed by the controlled crystallization of glass. George H. Beall from Corning Inc. talked about microstructural engineering of these materials to make them tough. Good flexural strength and fracture toughness can be obtained by creating an interlocking microstructure with isolated residual glass. Acicular chain silicates are the basis for the toughest glass-ceramics, which are currently used as durable tableware and surgical implants. Nanocrystalline versions can be polished like glass, but have elastic moduli, toughness, and hardness roughly double those of glass. These materials are under development as magnetic memory disk substrates.

A presentation by Anthony Evans of Harvard University on an integrated modeling approach from processing to performance covered the use of computer modeling and simulation to speed up the process of getting a materials research development from concept to product. Materials processing, performance, and cost requirements can be balanced to find the best manufacturing solution.

decreased in nanograined $LaNi_5$ when ball milled with Pd. This latter material is consequently particularly attractive as a medium for hydrogen storage.

Defects Affect Current Density of High-T_c Superconductors

High-temperature superconductors have moved steadily toward practical applications with fundamental knowledge keeping pace. The effects of defects on properties have captured attention and helped to further advances. Symposium F, Defects in High-Temperature Superconductors—Characterization and Relations to Processing and Properties, sought to examine the character and implications of defects. The term defects was taken in its broadest sense, ranging from point defects to grain boundaries to macroscopic heterogeneities such as second phases and cracks.

Coverage of flux pinning by defects included a talk by M. Murakami (ISTEC) on effects of rare-earth substitutions, such as Nd, Sm, and Eu, on Y-211 phase development and resultant intragranular critical current density, J_c. Substantial enhancement in J_c is induced by these substitutions because of the formation of fine-scale regions of depressed T_c. E.M. Ibragimova (INP, Tashkent) discussed flux pinning from irradiation-induced defects. Effects of atomic displacement could be separated from those of electronic excitation through the use of gamma, electron, and neutron irradiation. Changes in T_c of Y-123 single crystals with ^{60}Co gamma irradiation received most of the attention because this irradiation affects only the state of order on the oxygen sublattice.

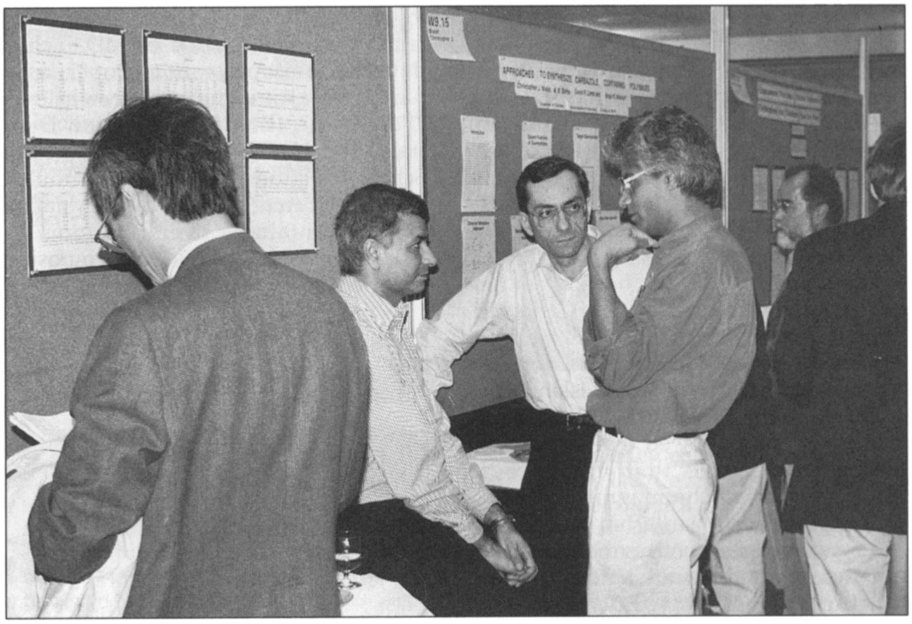
X. D. Wu (LANL) summarized the recent advances in J_c and mechanical properties of Y-123 films on Ni-alloy substrates with buffer layers of ion-beam-assisted deposited ZrO_2 or CeO_2/ZrO_2. Films 1.2 μm thick achieved bending strains of 0.5% with negligible loss of J_c. Oak Ridge National Laboratory results indicate that thick films on biaxially textured (by rolling) metallic substrates also have the possibility for very high current densities.

The presentations on new materials and bulk applications unanimously consider Hg-based components as good candidate materials for future application at extremely high temperatures. Fabrication of grain-oriented Hg-1223 conductors on Ni-based alloy substrates with J_c 2.5 x 104 A/cm^2 at 77 K in zero applied magnetic field was announced as was successful stabilization of Hg-based compounds and preparation of SQUIDs which operated above 110 K.

L. Gao (Univ. of Houston) and M. Alario-Franco (CNRS) reported the possible existence of a 124 K superconducting phase in high-pressure-synthesized samples in the Cu-Ba-Ca-Cu-O system, which would be the highest T_c for a material without a toxic element such as Hg or Tl. The structures and magnetic properties of various phases in Sr(Ca)-Cu-O system, showed promise of a new superconducting phase at high temperatures.

Clad Bi-2223 tapes showed improved current densities by the use of Ag-alloy sheaths containing 10% Cu and small concentrations of elements such as Hf or Ti. However, transport J_c values continue to be limited by defects such as cracks and gross nonsuperconducting phases and there is still no trivial correlation between microstructure and J_c.

Symposium Support: Niki-Glass Inc., Varian Assoc.



Researchers discuss their work at a poster session.

Epitaxial Oxides Studied by *In Situ* Techniques
(See MRS Proceedings Volume 401)

One of the highlights of the rapidly growing field of epitaxial oxide thin films (Symposium G) was the session on the giant magnetoresistive effect in mixed valence manganite perovskite materials. The symposium was kicked off by J.B. Goodenough (Univ. Of Texas—Austin), a veteran in this field with a deep understanding of the solid-state physics and chemistry. Not long ago, the area was dominated by thin-film deposition and thin-film bulk characterization. Now we see a trend toward a deeper understanding of growth mechanisms by *in situ* growth studies. On the other hand the materials quality of the films today is sufficient to be used in applications. Frequency doubling to produce short wavelength sources of coherent light and switching devices with built-in memory as presented in this meeting serve as examples.

Symposium Support: Philips Electronics Instruments, JEOL.

Grain Boundaries and Orientation Control Film Properties
(See MRS Proceedings Volume 403)

The aim of Symposium I was to study the structure and properties of polycrystalline thin films in which grain-boundary effects dominate film behavior, and the properties are intermediate between those of bulk materials and single-crystal films. In particular, the crystallographic orientation (texture) of the grains comprising the films has an important effect on film properties, so it is of interest to understand how the microstructure can be controlled. The symposium united work on structural evolution of polycrystalline films with work on film properties, particularly technologically important films used in devices such as sensors, microelectronics, information storage.

The symposium started with the evolution of microstructure and texture in thin films and film characterization methods, and continued with sessions on inter-

https://doi.org/10.1557/S0883769400036174 Published online by Cambridge University Press

faces, mechanical properties, and technological applications in the areas of hard coatings, polysilicon, electrical properties of films, optical properties of films, gas sensors, ferroelectrics, metallization, and magnetic applications.

Symposium Support: IBM Storage Systems Division, KOMAG Inc.

Dynamic Reactions Observed *In Situ*
(See MRS Proceedings Volume 404)

Symposium J, *In Situ* Electron and Tunneling Microscopies of Dynamic Processes, provided insight into recent advances in *in situ* techniques to probe dynamic reactions in materials science, chemical science, and technologies. The topics ranged from dynamics of semiconductor surfaces, catalysis, ceramics, and chemical vapor deposition (CVD) to integrated circuits (IC). Surface and interface structures under reaction conditions play a crucial role in controlling properties of solids, and fundamental understanding of dynamic atomic-scale structures is essential. Many of the current techniques used to characterize surfaces, interfaces, and epitaxial structures often employ postreaction static samples (i.e., reacted *ex situ* and cooled to room temperature) held in high vacuum, which are not representative of the dynamic state. Recent developments in *in situ* instrumentation and techniques have made studies of selected dynamic reactions possible.

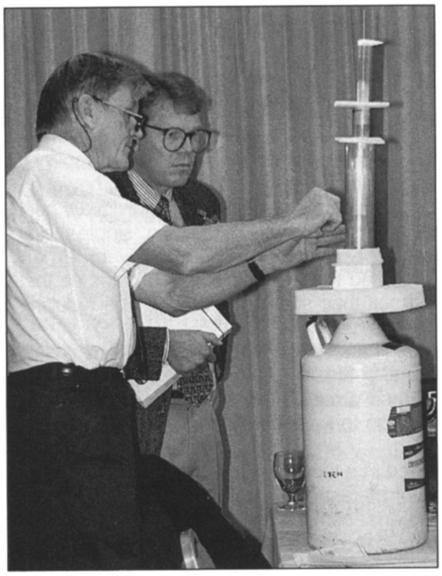
Several talks at the symposium elucidated the power of *in situ* electron microscopy (EM). Recent important advances included the development of an *in situ* controlled environmental cell (ECELL) high resolution EM (*in situ*-ECELL HREM) to probe dynamic gas-solid reactions at elevated temperatures directly at the atomic-scale. Using the method, a link between macroscopic properties and dynamic atomic-structural arrangement was demonstrated in oxides and ceramic-supported metallic nanoparticles, employed in catalytic process technologies. Other highlights included *in situ* analyses of aggregation of nanophase materials in an ultrahigh vacuum (UHV)-TEM, *in situ* CVD, environmental SEM (ESEM), vortex motion in superconductors by electron holography, and low-voltage-HRSEM for dynamic sintering studies of uncoated ceramics.

Semiconductor surfaces play a key role in device technologies in the semiconductor industry. Studies of surface dynamics included homoepitaxial growth in silicon by low-energy EM (LEEM), and thin-film growth dynamics by reflection EM (REM). Dynamics of semiconductor and metal surfaces were also reported using *in situ* STM for atomic-scale studies of point defects in silicon, surface-catalyzed reactions, and with a time-of-flight mass spectrometer for analyses. Electromigration void nucleation and growth dynamics were reported; these are failure mechanisms of IC metallization causing significant reliability problems.

Symposium Support: Gatan Inc., DuPont Science & Eng. Labs., Philips Electron Optics Co., JEOL, NSA Nissei Sangyo America Ltd., Omicron Assoc., ACS, RHK Technology, Inc., Park Scientific Instruments.

Interfaces of Nanostructures Engineered to Control Bandgap
(See MRS Proceedings Volume 405)

In modern electronics, reductions in device dimensions are necessary to increase packing density and speed. Thus, the objective of Symposium K, Surface/Interface and Stress Effects in Electronic Material Nanostructures, was to investigate the growth and fabrication of small structures, which lead to large surface-to-volume ratios and increase the importance of surface effects and the role of strain.



During a lab demonstration for the Workshop on Changing the Paradigm in Materials Education, Robert L. Zimmerman of Alabama A&M University (left) demonstrates vertical Bridgman crystal growth using water for the melt and ice for the crystal. He uses a clear plastic tube for the crucible, mounted on an aluminum cold finger secured in a Styrofoam plug in the top of a 20 l liquid nitrogen dewar. This system, used as a lecture demonstration or lab experiment, mimics semiconductors which have high conductivity melts (e.g., Si, GaAs, Te, HgCdTe).

The symposium started with a tutorial dealing with the effects of stress on the band structure of nanoscale semiconductor structures. An interesting use of controlled external stress was used to show Type I behavior of SiGe quantum wells. Other novel applications of stress in nanostructures included the use of stressor lines on GaAs to create arrays of quantum wires or dots for carrier confinement, without the need of fabrication and the problems associated with dry etching.

From the perspective of nanostructure fabrication by the use of dry etching, etching damage of the sidewalls led to significant residual strains, which decreased with the size of the nanostructure. The measurement of strains in these nanostructures was also an important issue, since many techniques only give an average strain value over a large sample area. One powerful local strain measurement technique involved the use of x-ray diffraction reciprocal space mapping. It was shown that information on strain, local geometry, and defect presence could be obtained, and local strain distribution of various quantum-well dots and lines, as well as oxidized silicon pillars, could be measured and monitored as a function of processing steps.

The importance of surfaces and surface chemistry on the optical behavior of group IV nanostructures was also addressed. It was shown that surfaces and/or the presence of chemical species (especially oxygen) were the controlling factors which determine the emission behavior in these materials. Similar to the behavior of porous silicon and microcrystalline silicon, nanocrystals of both Si and Ge were reported to exhibit visible emission independent of the size of the nanostructure, and the crystalline structure of the Ge clusters was found to be tetragonal and not diamond cubic. The source of the emission in all these nanostructures appears similar, and was discussed in terms of a surface state model, and a model based on an oxide-related interfacial defect.

Optical Techniques Dominate Semiconductor Diagnostic Techniques
(See MRS Proceedings Volume 406)

Symposium L, Diagnostic Techniques for Semiconductor Materials Processing, addressed the need in the semiconductor industry for a variety of *in situ* and *ex situ* diagnostic techniques. The overriding goal for rapid, accurate materials characterization, both *in situ* and *ex situ*, optical techniques were favored by most of the participants.

In the area of plasma processing, techniques such as Langmuir probes, optical emission spectroscopy, and mass spectrometry were discussed as probes of the plasma and the etch byproducts, while reflectance spectroscopies were used to monitor the wafers directly. In the area of materials growth, many authors discussed reflectance spectroscopies and laser light scattering techniques for monitoring the growth process in both molecular-beam epitaxy and chemical vapor deposition. Techniques for monitoring the sample temperature directly on the wafers were presented and they can be applied in both growth and etching environments. Simple and reliable diagnostic techniques that can be applied in industry were emphasized.

Ex situ materials characterization focused on the use of x-ray analysis for the characterization of physical properties such as strain in thin layers and nanostructures, thin-film densities, and the effects of dry etching. Device characterization consisted primarily of the use of electromodulation spectroscopy to probe device structures such as quantum-well lasers, heterojunction bipolar transistors, and high-electron-mobility transistors. These techniques were also applied to the characterization of materials processing.

Exciting scanning probe techniques such as atomic force microscopy (AFM) and scanning tunneling microscopy (STM), as well as near-field scanning optical microscopy (NSOM) were shown capable of addressing problems of interest in materials processing. These include the use of the STM and AFM in nanoscale lithography, the application of NSOM to heterojunctions, to materials having different phases, and to surface passivation.

As the techniques and their applications mature, researchers expect to see their applications in real-time feedback schemes for precise control of materials based on the discussions in this symposium; they expect to begin to see the application of the nanoscale spectroscopies in device processing.

Symposium Support: TopoMetrix, Instruments SA Inc., MKS Instruments Inc., Plasma Therm Industrial Products Inc.

Educators Debate Changing the Paradigm in Materials Education

The primary goal of the Workshop on Materials Education was to promote discussion and debate within the active community of materials educators. The workshop emphasized ambitious and pioneering initiatives which seek the most effective ways to communicate and teach materials topics, given current curriculum demands. The initiatives take advantage of new electronic aids—modular PC software, videos, and videoconferencing—and extensive accumulated experience in motivating and instructing students, and capturing their interest with state-of-the-art, real-life problem solving.

Eleven invited talks and 12 poster/software/hardware demonstrations reflected the tremendous effort underway, especially in creating new, integrated curricula at both undergraduate and graduate levels. The quality of modular software packages was particularly impressive. Topics ranged widely, including coordinated curriculum segments and illustrations of special phenomena for both undergraduate and graduate levels, and modules to assist high-school teachers.

One presentation that exemplified the goals of the workshop was given by K. Constant (Iowa State Univ.). She described the ongoing construction of modular course material in CD-ROM format that is intended to provide students and faculty with new detailed instruction, topic by topic, in a way that was specifically designed to capture student interest. More subtly, however, her design of modules is based on recognizing the various channels whereby individuals best absorb and retain information and understanding (balancing visual with audio; single-thrust focus with broad-based parallel advance; and exploratory hands-on with goal-driven). When possible, the course presentations are deliberately crafted to provide alternative paths so that students will, in principle, find approaches that best suit their styles of learning. The resulting examples illustrated a technically smooth, logical, self-instruction series.

K. Kolenbrander (MIT) described an undergraduate laboratory course on materials synthesis and processing. This course has evolved over several years. It challenges students to satisfy tough performance criteria for their new "product," and proceed (under faculty guidance) to invent both the engineering and materials-based solution to the problem, then devise a way to manufacture it.

The issues of curriculum development were debated in a lunchtime forum chaired by R. Roy (The Pennsylvania State Univ.). The development of materials curricula is clearly handled in many diverse ways, depending on the departmental arrangements on campus and the topical emphases of the graduate school. Among some practical concerns were a lack of an effective database or reference source whereby a teacher may know about software, modules, and books that are in preparation, and perhaps available for use. Another concern is that many materials educators are finding their efforts hampered by the poor mathematical skills of entering students.

The discussion also focused on the important role played in the process of advancement of materials teaching by the National Science Foundation (NSF) through funding exploratory programs and curriculum development. (In fact, this workshop was enabled by NSF support.)

An evening discussion was called to gather opinions on the preferred style and content for an upgraded *Journal of Materials Education*. The Workshop Proceedings Issue is planned to initiate a new era for the *Journal* by introducing a major focus on high-level, peer-reviewed articles dealing with the science and practice of pedagogical work in the materials area. It is a journal for the serious teacher, whose publications therein should be considered to be as credit-worthy as the top technical publications.

On the basis of the strong support for this workshop, and many expressed requests, MRS has already included plans for a sequel Workshop on Materials Education, to be held at the 1996 MRS Fall Meeting/ICEM-96, in Boston. Organizers for that workshop will be K. Vedula (Univ. of Massachusetts—Lowell), R. Abbaschian (Univ. of Florida), and J. Baglin (IBM Almaden Research Center). The organizers welcome suggestions for that program.

Research on Foams, Emulsions, Colloids, Liquid Crystals Flows Forward

One of the main highlights of symposium N, Complex Fluids, was a series of biophysics talks on such topics as motor protein function, fractionation of biological materials, and the structure and dynamics of biopolymer gels. By fabrication of submicron-size silicon-based arrays of obstacles, R. Austin (Princeton Univ.) has demonstrated the ability to separate such objects as cells and high-molecular-weight DNA. This offers the possibility of an alternative to traditional gel electrophoresis.

P. Janmey (Harvard Medical School) reported on the properties of cytoskeletal protein networks and gels demonstrated the important opportunities of such biological systems as models for the study of basic polymer science. Both macroscopic rheological measurements and direct video imaging of the dynamics of individual filaments was reported.

S. Dierker (Univ. of Michigan) presented the extension of dynamic light scattering techniques to the x-ray domain. This new field of x-ray photon correlation spectroscopy (XPCS) offers an unprecedented opportunity to study the dynamics of materials down to interatomic spacings.

Symposium Support: Exxon Research & Eng. Co., ONR.

Building Structures from the Bottom Up

The importance of self-assembly for materials science is that ultrasmall, or highly complex, or uniform, large area structures are formed spontaneously (a "bottom-up" process) based on intermolecular forces that can uniquely dictate the form or pattern of the final structure. The elimination of complicated or laborious "top-down" processing steps can lead both to new materials that are not obtain-

https://doi.org/10.1557/S0883769400036174 Published online by Cambridge University Press

able by conventional techniques, and also to new, simplified paradigms of cost-effective manufacturing.

In Symposium O, considerable progress was reported in the development of self-assembled monolayer (SAM) films for tailoring physical and chemical surface properties of substrates. Patterned SAM film surfaces, fabricated by photochemical, electron beam, or contact printing techniques, were used as templates for high resolution, selective area deposition, or attachment of metals, oxides, colloids, clusters, polymers, and biological materials; these surfaces are receiving increasing attention for use in electronics, sensors, and optical applications.

Ordered films formed by self-assembly of organic semiconductors or polycyclic aromatic hydrocarbons were shown to function as active elements of thin-film transistors or quantum-well electronic structures. Peptide chemistry was a key component in the development of spherical, cylindrical, or planar microstructures whose dimensions and chemical properties are tuned by molecular-level manipulation of constituent units. Self-assembly of proteins was shown to produce regular structures with nanometer-scale periodicity (bacterial S-layers) or extremely robust, lightweight fibers (spider silk). Self-assembled phospholipid tubules were demonstrated as vehicles for controlled release drug delivery. Sequential adsorption of polyelectrolytes or metal phosphonate synthesis were shown to be highly versatile methods for producing bulk films having spatially nanostructured composition which also allow the incorporation of a large variety of chemical entities (polymers, fullerenes, proteins, DNA, colloids) into separate, well-defined layers. Such multilayer superlattices were shown to be useful for applications in polymer LEDs with enhanced transport characteristics, x-ray reflectors, and shape-selective membrane applications. Phase separation in block copolymers or spontaneous ordering of ferroelectric liquid-crystalline polymers were also reported as an effective means of producing 3D-structured materials for electro-optical applications.

Symposium Support: Elsevier Science Ltd., ONR.

Multimillion-Atom and Macroscopic Simulations Model Fracture
(See MRS Proceedings Volume 409)

Symposium Q, Fracture-Instability Dynamics, Scaling, and Ductile/Brittle Behavior, contained an interdisciplinary collection of theoretical and experimental papers aimed at the fundamentals of fracture behavior. The theoretical methods ranged broadly from atomic-level simulations to macroscopic modeling.

In some of the most extensive simulations of crack-tip behavior to date, a Los Alamos group used over three million atoms to simulate the breakdown of a crack tip in copper. Emission of homogeneously nucleated dislocation loops in several geometries was clearly established. At the other extreme, models for composites were presented based on fuse networks symbolizing much larger entities; these studies provide a promising route to computer-aided design of such materials. Several dynamic-fracture papers treated the instability and branching that occurs for high-speed cracks in many materials. A pervasive theme was the increasing success of attempts to "join up" atomic-level calculations with more coarse-grained approaches.

Experimental papers emphasized impurity embrittlement, interfacial adhesion, the toughness of ceramics and composites, and the morphology of fracture surfaces. In connection with the latter, several papers showed that a fractal fracture surface should be thought of as self-affine rather than self-similar—in each case, the surface has scaling properties, but in the latter case the scaling perpendicular to the surface is different from that parallel to the surface.

Symposium Support: ONR.

Federico Capasso (AT&T Bell Labs), one of the recipients of a 1995 MRS Medal, gives his talk, "Bandgap Engineering of Compositionally Graded Semiconductors: Physics and Applications to Electronics and Photonics," as a part of Symposium CC, Spectroscopy of Heterojunctions.

Chemical Degradation of Cement Related to Microstructure

Whether cement-based materials are to be used in infrastructure systems or wasteforms, assurance of adequate service life performance is critical for safe and cost-effective applications. Symposium R on Mechanisms of Chemical Degradation of Cement-Based Systems—Toward Service Life Prediction addressed this broad issue on several fronts, involving thermodynamics, kinetics, and mechanics. The degradation processes that were of greatest interest were chloride-induced corrosion of reinforcing steel, carbonation, sulfate attack, and delayed ettringite formation. This last item has been the subject of intense inquiry following major failures in steam-cured concrete railroad ties. Groups working on this problem appear now to have reached near unanimity regarding the levels of sulfate, alkalis, and curing temperatures required to initiate this problem. Expansion is due to submicron ettringite closely intermixed with amorphous calcium silicate hydrate (C-S-H); crystallization of more massive ettringite is a secondary, nonexpensive process. Delayed ettringite is distinct from external sulfate attack. The progressive ingress of sulfate and accompanying damage was clearly documented. Gypsum formation contributes to progressive surface macrocracking when Portland cement is the binder, but in slag-cement blends decalcification of C-S-H leads to an overall weakening of the matrix. The decalcification of C-S-H by prolonged leaching with water was also reported.

Destruction of the passive iron-oxide layer on reinforcing steel by the chloride ion is being examined by several groups. Nitrites oxidize ferrous ions which are susceptible to dissolution by chloride. Electrochemical impedance spectroscopy shows that the passive film is rapidly destroyed by high chloride ion concentrations. Thus, quantitative modeling of this process is giving the rate of diffusion of chloride ions through concrete. The proceedings will be published in early 1996 by E&FN Spon Ltd.

Symposium Support: Portland Cement Assoc., Lafarge Fondu Internat'l, NSF.

Covalent Ceramics Processed and Characterized

(See MRS Proceedings Volume 410)

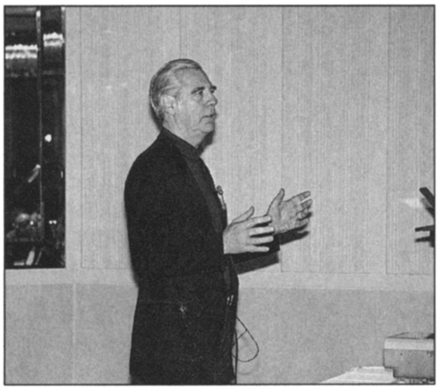
Symposium S was the third installment in an on-going series of symposia on the broad range of materials for covalent ceramics (Science and Technology of Non-Oxides). The symposium described the processing and properties of bulk (including composite) and thin-film carbides, sulfides, selenides, and nitrides for both electronic and structural applications.

A.R. Barron (Rice Univ.) described a new class of GaAs devices enabled by CVD-deposited cubic GaS from an organometallic GaS complex. The structure of the cubic tetramer is retained to produce a phase of GaS that is not obtainable by any other processing technique. The GaS has a high bandgap (about 4 eV) and chemical stability that lends itself to the formation of metal insulator semiconductor field effect transistor.

Several presentations were given on the novel production of metal carbides and nitrides. Among these findings were the use of carbon nanotubes to produce nanorods of TiC, NbC, and SiC and characterization of the properties of the nanorods; a simple electrochemical method for producing a number of different transition metal and main group metal nitrides; and preparation of ternary nitrides via solid oxide or molecular precursors.

The contributions of most interest in this symposium involved thin films, SiC, GaN, electronic applications, and novel processing of carbides and nitrides. However, the range of topics and the intent to focus on underlying, fundamental issues common to covalent ceramics can be appreciated by the following list of presentations on processing issues of thin-film solar cell materials, II-VI layers and quantum dot composites, high-pressure behavior of iron sulfide and implications for iron-bearing cores of planetary bodies, silicon nitride-molybdenum disilicide composites, and several papers on thin-film deposition of hard carbides and nitrides.

Symposium Support: Aluminum Research Board, MKS Instruments, Viable Internat'l Technology Assoc.—Industrial Plant, NY State CAT on Thin Films & Coatings, NASA Lewis Research Center.



Didier de Fontaine, the 1995 MRS Turnbull Lecturer and professor of materials science and engineering at the University of California—Berkeley, presents his talk, "From Gibbsian Thermodynamics to Electronic Structure: Nonempirical Studies of Alloy Phase Equilibria" as part of Symposium P, Materials Theory, Simulations, and Parallel Algorithms.

Defects, Microstructure Probed Electrically

(See MRS Proceedings Volume 411)

The application of electrical measurements for the detection of microstructural features at all length scales (atomic to macroscopic) was the subject of symposium T, Electrically Based Microstructural Characterization. Topics included the characterization of the microstructural features in ionic conductors, superconductors, ferroelectrics, semiconductors, and metallic conductors. All classes of materials were covered including electroceramics, biological materials, polymers, metals, and various types of composites. Of note were papers dealing with new applications of impedance spectroscopy to ferromagnetic materials and resolving microstructural features on a local level.

Some of the salient papers included the detection of defects in a wide variety of materials including II-VI compounds and ferroelectrics, monitoring of solder flux during processing, electromigration and stress in VLSI interconnects, correlation of mechanical to electrical behavior in composites, and use of dielectric sensors for detecting changes in the environment as well as in construction materials (such as cements and concrete).

Symposium Support: Solartron Instruments, Keithley Instruments Inc.

Nuclear Waste Management Faces Problems Related to Defense Waste

(See MRS Proceedings Volume 412)

Commercial spent nuclear fuel and borosilicate glass high-level nuclear waste forms received widespread attention at Symposium V. In addition, the dispositioning of less conventional high-level nuclear waste materials related to nuclear defense activities attracted much attention. R.L. Garwin (IBM Fellow Emeritus) was a member of the National Research Council panel on the dispositioning of excess weapons plutonium and presented an invited paper on this subject. Dismantlement of thousands of Russian and U.S.

Employment Services Introduce Career Workshop and Networking

Michal Freedhoff and Karen Moore, members of the University of Rochester Chapter of MRS, organized two additional features to the usual employment services at the 1995 MRS Fall Meeting. One was a Career Workshop held on Sunday afternoon and the other was a networking element to the Student Mixer.

The American Institute of Physics (AIP) was contracted to present the workshop. Moore and Freedhoff helped AIP tailor the program toward materials science and engineering. Topics included statistics on materials science and employment, networking, and resume writing. Mock interviews were also held.

The Student Mixer encouraged student chapters to present posters detailing their efforts and activities, particularly in the areas of job placement services for their membership. Awards consisting of meeting registration reimbursement were partly responsible for posters from Massachusetts Institute of Technology, University of California—Berkeley, University of Connecticut, University of Florida, University of Rochester, and the University of Washington. Executive officers of MRS, corporate affiliates, and exhibitors were personally invited to attend in order to informally talk about job prospects with the student membership.

These events were sponsored in part by a grant from the MRS Special Projects subcommittee.

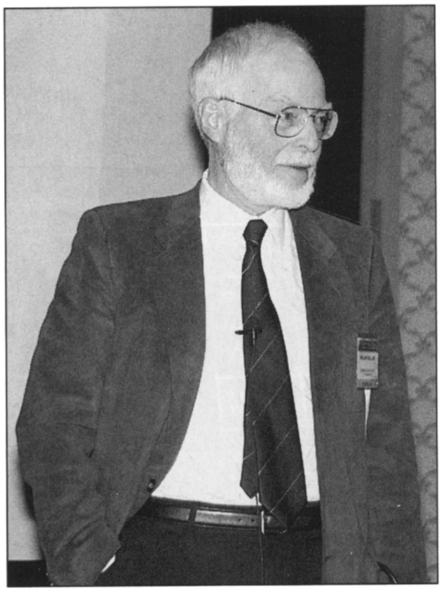
https://doi.org/10.1557/S0883769400036174 Published online by Cambridge University Press

nuclear weapons and related activities will produce more than 100 tons of excess weapons grade plutonium by 2003. The dangers of weapons proliferation and unintentional criticality, as well as radioactivity, require careful control and dispositioning of this material. Of numerous possibilities, two recommendations were provided on the basis of security, legality, practicality, and economy. One disposal method is to mix excess plutonium in borosilicate glass logs designed for disposal of fission products generated during original plutonium production. This waste form is destined for permanent disposal in a mined geologic repository. Presently Yucca Mountain, Nevada, is being studied as the potential high-level waste repository site. The second recommendation is to mix the plutonium with depleted uranium to produce mixed-oxide ceramic fuel for use in power-generating nuclear reactors. The spent fuel generated by this process would also be destined for the nation's geologic repository for high-level nuclear waste.

An alternate waste form for excess plutonium, the zirconium silicate mineral zircon, was proposed in two other presentations. Zircon is a highly durable natural mineral with a low dissolution rate. W. Lutze (Univ. of New Mexico) presented a paper he coauthored with W.J. Weber (PNL) and R.C. Ewing (Univ. of New Mexico). They note that zircon can incorporate at least a 10 wt% plutonium in substitution for zirconium in its structure. By combining laboratory data with observations of natural zircons they estimated the effects of radiation on zircon over time periods relevant to permanent isolation of nuclear waste and as a function of temperature. Radiation damage causes zirconia to become amorphous with an increase in volume. However, at elevated temperature, annealing overcomes radiation effects. Another paper on zircon was presented by B.E. Burakov, and coauthored by E.B. Anderson, V.S. Rovsha, and S.V. Ushakov, all from the Khlopin Radium Institute in St. Petersburg, Russia, and also Ewing, Lutze, and Weber. They developed a new method for synthesis of actinide-doped zircon based on observations of zircon crystallized from the molten reactor core at Chernobyl. Mixtures of zirconium metal, uranium or lanthanide (analog of actinide) oxide, and silica were submitted to elevated temperature (1000 to 1500°C) and pressure (30 to 4,500 MPa), and uranium- and lanthanum-containing zircons were formed.

An uncommon nuclear fuel is composed of uranium aluminide clad in metallic aluminum. Approximately 450,000 kg of used fuel of this type is in the possession of the Department of Energy. The dispositioning of aluminum-clad spent fuel was addressed in a paper presented by M.R. Louthan, Jr. and coauthored by N.C. Iyer, R.L. Sindelar, and H.B. Peacock, Jr. all of the Savannah River Technology Center. Special difficulties attend this waste form since it is highly enriched in fissile uranium 235, because aluminum and uranium aluminide have poor corrosion resistance, especially at elevated temperatures. Temperature will rise in the proposed geologic repository due to radioactive decay and may exceed acceptable temperatures for aluminum clad fuel. Placement of this waste at the margins of the repository where temperatures will be lower engenders other problems. The margins are likely to be wetter, which could induce more rapid corrosion and increased potential for criticality and radionuclide release. Also, the margins of the repository may be a target for covert removal of the highly enriched uranium. Dispositioning of aluminum clad fuel in a high-level waste repository presents challenging, and as yet unresolved, repository performance issues.

Symposium Support: Nuclear Regulatory Commission, ANL, Southwest Research Institute, Power Reactor & Nuclear Fuel Development Corp., British Nuclear Fuels.



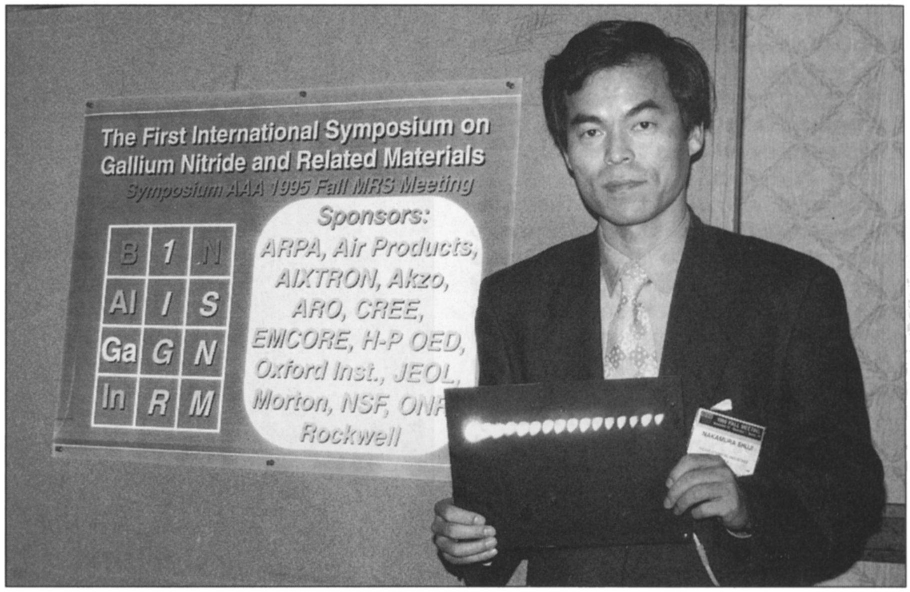
William W. Mullins, recipient of MRS's highest honor, the Von Hippel Award, and professor emeritus of Carnegie-Mellon University, gives a talk on the evolution of materials science. The Von Hippel Award recognized Mullins for "pioneering interdisciplinary, profound, and useful contributions to materials science and engineering, including the dynamics of microstructural change, especially grain boundary motion; the quantitative theory of morphological change and instabilities; modeling of the step structure of surfaces and interfaces; and stochastic modeling of diffusion and particulate flow; as well as didactic and pedagogical contributions to generations of students and colleagues."

Specific Responses of Biological Tissues to Surfaces Sought
(See MRS Proceedings Volume 414)

Symposium Z on Thin Films and Surfaces for Bioactivity and Biomedical Applications emphasized various methods of thin-film preparation and surface modification, as well as results of *in vitro* experiments designed to assess biological responses to surfaces. The goal of most of the work reported was to create and modify surfaces that would elicit *specific* biological responses.

Five invited speakers addressed different aspects of these issues. T.G. Vargo (Geo-Centers, Inc.) described modifications to FEP materials and subsequent fluorescence studies of dansylchloride-labeled ablumin in contact with the materials. The protein in contact with a peptide-modified FEP (FEP-APTES) was more denatured than protein in contact with the unmodified FEP control. I-H. Loh (Advanced Surface Technology, Inc.) outlined the various effects of gas plasma treatment of biomedical materials, including radical formation and its subsequent effects on material performance. R. Langer (MIT) described the use of polyanhydrides in chemotherapy for the treatment of brain tumors and transdermal drug delivery by ultrasound techniques. The BCNU drugs used in brain tumor chemotherapy regimens have severe negative side effects that can be minimized with a local delivery system that involves exposing only particular cells to the BCNU drug by lining the implantation cavity with a polyanhydride polymer. In clinical trials, the two-year survival rate was 31% with the anhydride liner versus 2% without. Langer also reported that the mechanism of transdermal drug delivery by ultrasonic means is cavitation. The efficiency of delivery has been increased dramatically by recognizing the inverse relationship between cavitation and frequency. Huge fluxes are possible at low frequency, which reduces the time required for typical dose delivery. (See *MRS Bulletin*, August 1995, p. 18, for a transcript of Langer's 1995 MRS Spring Meeting plenary lecture on this topic.) B. Ratner (Univ. of Washington—Seattle) discussed the vagaries of the term "biocompatible" and the necessary complexity of *in vivo* responses. Ratner encourages the use of self-assembled structures to obtain specific biological reactions. The self-assembled components should be formed within or on a biologically "bland" background. J.E. Davies (Univ. of Toronto) demonstrated that bony mineralization occurs into pores and spaces much smaller than previously thought to be possible (1-2 μm vs. 100-300 μm) due to the ingrowth of active cell processes and not the whole cells themselves.

Symposium Support: Howmedica Inc., Physical Electronics Inc., ORNL.



Shuji Nakamura of Nichia Chemical Industries, Ltd. displays InGaN-based LEDs during Symposium AAA, The First International Symposium on Gallium Nitride and Related Materials. The quantum-well structure LEDs which have a thin InGaN active layer have been developed in order to obtain high-power emission in the color region from blue to yellow with a narrow emission spectrum. The typical blue LEDs had a peak wavelength of 450 nm and the full width at half-maximum (FWHM) of 20 nm. The output power, the external quantum efficiency, and the luminous intensity of blue LEDs at a forward current of 20 mA were 5 mW, 9.1%, and 2 cd, respectively. The typical green LEDs had a peak wavelength of 520 nm and the FWHM of 30 nm. The output power, the external quantum efficiency, and the luminous intensity of green LEDs at a forward current of 20 mA were 3 mW, 6.3%, and 12 cd, respectively. The luminous intensity of green LEDs (12 cd) was about 100 times higher than that of conventional green GaP LEDs (0.1 cd).

Target-Costing for Manufacturing Leads to Comparative Materials Selection

The goal of Symposium AA, Low-Cost Manufacturing of Materials, was underscored most appropriately by a paper on "target costing" and its implication to the research community. Target costing is a discipline imposed by the marketplace which puts a cap on the acceptable price that the market would tolerate. Manufacturers then have to back out the costs they must meet in manufacturing an article after allowing for dealer and manufacturer margins. This forces the R&D and design communities to make choices between cost and performance without sacrificing quality. The theme of cost was continued in a paper on technical cost modeling of materials by C. Mangin (Ford). This type of modeling provided a mechanism for making the critical tradeoff in the selection of materials for a large class of problems. S. Savkar (GE) gave a paper on how target costing discipline forced such choices in the development of a new washing machine. The orchestration of the symposium theme was then rounded out in talks by J. Gudas, C. Allocca (both of NIST), and B.M. Kramer (NSF) on their cooperative programs to enhance the global commercial competitiveness of the U.S. industry and the outstanding example of NIST's manufacturing initiative at Cleveland State University which is refostering the traditional emphasis on design.

Presentations on structural materials in manufacturing included a talk about the materials substitution carried out on automobiles to reduce their weight and thereby increase their mileage, on low-cost automobile castings, an upbeat assessment of low-cost, thermal-spray forming using water-based plasmas, and on a reconfigurable tool useful in flexible manufacturing. The highlights of the sessions on composites and ceramics and on electronics and specialty materials, were a paper exploring the economic feasibility of high-temperature composites, and a paper on low-cost composite processing.

Symposium Support: Ford Motor Co., GE.

Diamond Emitters Grown for Electronic Applications

(See MRS Proceedings Volume 416)

The theme of Symposium DD, Diamond for Electronic Applications, was the state of the art in diamond growth and diagnostics, and implementation of that knowledge in specific electronic applications. Electrical and thermal characterization of electronic-grade diamond growth were examined, including recent developments in oriented polycrystalline growth on heteroepitaxial substrates, and homoepitaxial "mosaic" growth and separation from adjacent diamond substrates. The most intensively discussed application was diamond as an electron emitter, due in large part to the negative electron affinity (NEA) of some diamond surfaces. Electron emission from diamond was generally reviewed in the tutorial, and was followed by numerous presentations on the role of material properties on emission from diamond and related materials. Emphasis was placed on the roles of doping (especially *n*-type) and morphology on injection at the back-contact, and doping and lattice quality on electron transport through diamond. Numerous presentations explored the crucial role of surface chemistry in determining the electron affinity of diamond. Hydrogen termination was essential to a low work function, although hydrogenated surfaces covered with thin metal or alkali metal layers also exhibited stable NEA.

Substantial discussion centered on the relative economic and technological advantages of diamond, diamondlike carbon, and other wide bandgap semiconductors in particular for applications such as flat-panel displays. A review of commercial research and development of flat-panel displays from these materials was presented. Other applications discussed included diamond strain, pressure and gas sensors, switches, amplifiers, and radiation detectors.

Symposium Support: AT&T Bell Labs., Kobe Steel, Ballistic Missile Defense Org.

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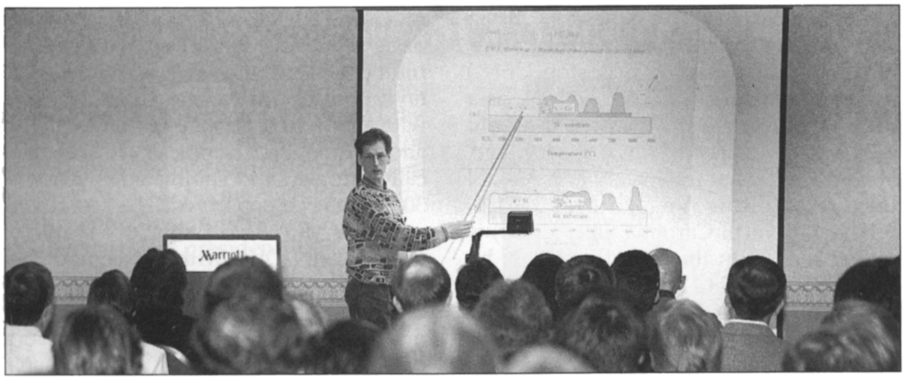

R.M. Tromp, one of the 1995 MRS Medal recipients, of the IBM T.J. Watson Research Center presents his talk, "Si(001) Homoepitaxial Growth," as part of Symposium J, In Situ *Electron and Tunneling Microscopy of Dynamic Processes.*

Compositionally Modulated Stable Quantum-Well Lasers Reported

(See MRS Proceedings Volume 417)

A session on Spontaneous Ordering in Semiconductors in symposium EE, Optoelectronic Materials—Ordering, Composition Modulation, and Self-Assembled Structures, had many participants from the United States, Germany, Sweden, and Japan. This symposium apparently had the most number of investigators under one roof at any time for this subject. Because of the audience's favorable response to the papers, contributed and invited, the symposium organizers arranged for an informal round table discussion on the future trends and applications of spontaneous order in semiconductors. About 30 investigators participated and all were given an opportunity to either express their opinions or present new thoughts on this subject.

A joint session with Symposium D, Evolution of Epitaxial Structures and Morphology, elicited the latest experimental and theoretical thoughts on self-assembled structures in semiconductors.

The last day of the symposium had two oral sessions, "Composition Modulation in Semiconductors" and "Materials for Optoelectronics." Both sessions had lively discussions. In particular, the invited paper by K.Y. Chang of Illinois aroused much interest and many questions about his reported laser devices based on compositionally modulated structures grown by molecular-beam epitaxy. Quantum wire arrays were produced by strain-induced lateral-layer ordering. Long wavelength (1.7 μm) and visible (0.7 μm) lasers were made of GaInAs and GaInP, respectively, with unprecendented wavelength stability with temperature. No pre-growth substrate patterning, or post-growth processing is needed.

Symposium Support: Nat'l Renewable Energy Lab., SNL.

Fullerenes Layer It On

Symposium FF on Fullerenes, Buckytubes, and Related Materials—Science and Applications focused on nanotubes, encapsulation and impregnation of atoms in the hollow fullerene molecules, molecular derivates, superconducting and other alkali fullerides, and the optical spectroscopy and properties of fullerenes. The opening presentation by S. Amelinckx (Univ. of Antwerp, Belgium) on transmission electron microscopy (TEM) studies of the textures and formation mechanisms of nanotubes clarified the mechanisms of formation of axially concentric layers of the nanotubes, and their growth into helical structures through opposing pentagons and heptagons with opposite curvatures. This presentation was particularly timely in view of the very recent achievements of Walt de Heer of the Swiss Federal Polytechnical Institute of Lausanne, who succeeded in fabricating ordered vertical arrays of nanotubes to be used as field emittors in plasma-based flat panel displays (*Int. Herald Tribune*, November 26, 1995).

Amelinckx's presentation was appropriately followed by a presentation of C.J. Brabec (North Carolina State Univ.) on simulations of nanotube formation, including the formation of pentagons, hexagons, and heptagons. These demonstrated the microscopic dynamical origins of the observations described by Amelinckx.

Studies on modifying multilayer carbon nanotubes into unique nanocomposites, notably filling nanotubes by capillarity and the characterization of such systems were described. These frontier studies will have a direct impact on technologies that will emerge from these fundamental studies of nanotubes.

Symposium Support: Ames Lab., Quantum Design Inc.

Complexities of Combustion and Detonation Studied

(See MRS Proceedings Volume 418)

The processes associated with decomposition, combustion, and detonation of energetic materials are immensely complex. Advancements in understanding these complexities are hard won because of the dynamic interplay of physical and chemical forces in the heterogeneous state, frequently on short timescales, and with short linear dimensions as evidenced in Symposium GG, Decomposition, Combustion, and Detonation Chemistry of Energetic Materials.

Progress in the understanding of energetic materials from the initial synthesis, to the nonreacting state, and finally to decomposition on the timescales from hours to picoseconds has markedly advanced in recent years. A major factor has been the incorporation of advanced diagnostics such as AFM, broadband time-resolved spectroscopy, laser methods, high-level theory, and high-speed computing. New and unusual compounds, which have been sought on the basis of theoretically optimized properties, are progressing from imagination to reality. Control over physical properties, such as defect number and crystal growth characteristics, is occurring. Progress is being made in new levels of understanding about reaction pathways, kinetics, sensitivity mechanisms, combustion mechanisms, and shock fronts. The focus on component materials has continued to expand beyond studies of the neat oxidizers and monopropellants to the behavior of binders, metals and metalloids, and whole new classes of compounds.

Symposium Support: ARO, ONR, LANL, LLNL.

GaN and Related Compounds Grow and Glow

(See MRS Proceedings Volume 395)

The First International Symposium on Gallium Nitride and Related Materials (ISGN-1) was held as Symposium AAA. This meeting was organized to provide a forum for the rapid dissemination of the latest information on the III-V nitrides.

H. Amano (Meijo Univ., Japan) discussed the status of the metalorganic chemical vapor deposition (MOCVD) work he and I. Akasaki are doing on AlGaN/InGaN structures. This included

https://doi.org/10.1557/S0883769400036174 Published online by Cambridge University Press

a review of their work on molecular beam epitaxy (MBE) and MOCVD growth of III-V nitrides on 6H-SiC substrates. He reported optically pumped stimulated emission at 377 nm for MOCVD $Al_{0.15}Ga_{0.85}N/In_{0.06}Ga_{0.94}N$ double heterostructures (DH) with 300 K thresholds of ~40 kW/cm^2, a value which is very low. Amano also described MOCVD-grown AlGaN/InGaN/GaN injection DH diodes grown on SiC with 300 K stimulated emission thresholds of ~27 kW/cm^2, although these devices were "unstable" and could not be evaluated for true laser action. P.A. Maki, et al., from Lincoln Laboratory at Massachusetts Institute of Technology reported on "thick" GaN films grown on *c*-plane sapphire by vapor phase epitaxy (VPE) using HCl, Ga metal, and NH_3 as sources. The VPE thick GaN layers were subsequently used as substrates for gas-source molecular-beam epitaxy (MBE) growth of AlGaN/InGaN/GaN heterostructures. These DH structures exhibit stimulated emission at 77 K at a threshold of 300 kW/cm^2 and 500 kW/cm^2 at 300 K.

In the area of MBE growth of III-V nitrides, T.D. Moustakas (Boston Univ.) used an ECR-plasma source with N_2 as a nitrogen precursor and grew InGaN alloys throughout the composition range. He has found that the InGaN and AlGaN ternaries follow Vegard's Law. J.F. Schetzina (North Carolina State Univ.) is concentrating on the growth of GaN by MBE on GaN/SiC heteroepitaxial substrates grown by Cree by MOCVD. He has shown AlGaN/GaN DH LEDs emitting at ~400 nm and InGaN/GaN LEDs emitting in the blue and green. O. Brandt, et al. (Paul Drude Institute, Berlin) reported on the growth of cubic GaN on (001) GaAs by MBE and the growth of InGaN by atomic layer epitaxy (ALE). Also discussed was the growth of alloys in the GaAs-GaN ternary system. The cubic GaN produced by MBE had some mixture of the wurtzite phase as well. In addition, the best cubic GaN exhibited 300 K photoluminescence (PL) spectra with a FWHM of 100 meV, still broad by most standards. M. Koike, et al. (Toyoda Gosei, Japan) has done work on MOCVD growth of III-N multiple-quantum-well (MQW) materials on sapphire, and has grown InGaN QWs with 8% In and thicknesses of L_z~3, 5, 7, and 10 nm. These samples have been optically pumped and stimulated emission at 300 K has been observed. The best results are for a MQW with an active region of three InGaN QWs with x~0.08 and L_z~7 nm. Cree Research (H-S. Kong, et al.) described blue LEDs grown by MOCVD on (0001) 6H-SiC substrates. This work has shown "blue-emitting" AlGaN/GaN/SiC LEDs operating at 468 nm. In addition, optically pumped AlGaN/GaN DH laser structures with stimulated emission at input powers of ~50 kW/cm^2 have been demonstrated.

Symposium Support: ONR, NSF, ARO, Air Products and Chemicals Inc., JEOL, EMCORE, Morton Internat'l, HP, Rockwell Internat'l, AIXTRON, AKZO Chemicals, Cree Research, Oxford Instruments.

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