1996 MRS Spring Meeting Echoes Call of Materials Community

As researchers leverage resources and work toward practical ends, the strong interactions among colleagues and competitors have become increasingly important. The 1996 MRS Spring Meeting is testimony to this way of doing business, with by far the largest turnout for an MRS spring meeting (nearly 3,200 attendees for 2,500 oral and poster presentations), a growing participation in tutorials in which over 90 attendees gathered to learn about ferroelectrics on a holiday weekend, and real-time interaction causing a buzz in the hallways.

The 29 parallel technical symposia, along with Symposium X on Frontiers of Materials Research, scheduled April 8–12, 1996 in the San Francisco Marriott were orchestrated by Meeting Chairs Thomas F. Kuech (University of Wisconsin—Madison), Clifford L. Renschler (Sandia National Laboratories), and Chuang Chuang Tsai (Xerox Palo Alto Research Center). Darrel R. Tenney, Chief of the Materials Division of the National Aeronautics and Space Administration's (NASA) Langley Research Center, gave the plenary talk on aerospace materials research. During the plenary ceremony on Monday night, award recipients were honored for the Outstanding Young Investigator Award and the Graduate Student Awards. The exhibit, sold out at 123 booths, was open from Tuesday through Thursday.

Over 2500 oral and poster presentations were given at the MRS 1996 Spring Meeting in San Francisco.

The meeting filtered news to attendees about amorphous silicon solar cells moving into production, new flat-panel display technology, wide bandgap materials for electronics including the newly popular GaN, a wide assortment of information storage technologies, and other materials moving into the marketplace—even synthetic materials for banjos and guitars. A new venture for the Society was Symposium AA, Innovations in Instrumentation for Materials Research, which was an outlet to share instrumentation innovations that are produced by researchers in the course of their work.

Alongside the trend toward goal-oriented research is the continued study of fundamentals and modeling to understand why some materials work and others fail, despite intuitive expectations to the contrary. Building on the understanding of the connection between structure and behavior both on a macroscopic and atomic level, the time is nearing when it will be possible to construct identical materials structures by subtractive processing from the bulk or additive processing from atomic or molecular building blocks.

This increasingly sophisticated control over materials microstructure was reflected by several of the symposia. Symposium Y covered the fabrication of increasingly complex structures from small molecule precursors. Within this symposium, the 1996 MRS Outstanding Young Investigator described how to controllably build new body tissue aided by the influence of implantable materials (see sidebar.)

The past several years have seen explosive growth in research on both microporous and mesoporous molecular sieves. In accord with this interest, Symposium P covered major advances in synthesis, characterization, and exploitation of the possible mechanisms of formation of porous materials. Central to this topic is controlling the porosity such as by organic derivatization of silica gel surfaces, use of organic templates, and capillary stress control. Synthesis of a new zeolite was reported in which pentamethylcobaltacinium cation has been used to template the structure. Although complete details of the new structure were not given, it was hinted that this material may be the first zeolite with *a larger than 12 T-atom ring.*

The 7th symposium in the series on Better Ceramics Through Chemistry (Symposium V) narrowed its focus and concentrated on synthesis, structure, and properties of organic/inorganic hybrid materials. Several groups have achieved molecular scale porosity by plasma or thermal pyrolysis of organic moieties. Ceramic-like hardness and polymer-like processability have been combined to achieve adherent coatings with impressive scratch resistance. Toughness can be improved for instance by adding siloxane chains to porous silicate aerogels, or chloroplasts can be added to other materials for photosynthesis.

Symposium W, Computational Materials Science—Structural, Mechanical, and Transport Properties, aimed to bridge size and time scales by linking approaches ranging from quantum methods used for electronic structure and atomic force models to macroscopic methods employing finite element analysis used to understand mechanical and thermal properties. It was frequently observed that modeling the behavior of advanced materials required the use of hybrid computational techniques in order to span a vast range of length and time scales.

Layered materials and systems based on metallic, intermetallic, polymeric, and ceramic constituents are finding use as thermal barrier coatings, aircraft structural components, and wear resistant coatings. Symposium U, Layered Materials for Structural Applications, presented a spectrum of processing techniques such as e-beam deposition, reactive sputter deposition, sedimentation processing, pressureless co-sintering, and rapid prototyping. The mechanical behavior and modeling of layered systems revealed significant effects of layer thickness, spacing, and constituent properties on fracture and fatigue behavior of such systems.

Of particular interest in Symposium CC, Thin Films: Stresses and Mechanical Properties VI, was a joint study at the Naval Research Laboratory and the University of Minnesota, which gave a staircase load displacement profile in gold single crystals somewhat at variance with previous studies. Resolution of such differences should lead to in-depth understanding of nonlinear effects at metal surfaces undergoing nanometer level displacements.

Symposium L, Materials Reliability in Microelectronics VI, blended new developments with an historical perspective of the field. Nearly a full day of well-attended papers on oxide reliability attested to the growing importance of this area in the symposium. A special session of pioneers from the past 30 years in the field had a positive, vibrant air, but also revealed the competition, contention, and secrecy wrapped up in the early and expensive race to alleviate this significant technological impediment to integrated circuit development (see page 75).

Symposium J, Thin Films for Photovoltaic and Related Device Applications, showed that thin-film $Cu(In,Ga)Se_2$ solar cells of about 17% efficiency have been achieved in the United States, Japan, and Europe, underscoring the promise of this class of materials for photovoltaics applications. Also it was predicted that 15% efficiencies can be obtained from thin-film Si on substrate cells using low quality silicon with lateral grain sizes as small as 5 μm. Solar cells incorporating microcrystalline silicon absorber layers have achieved a 13.1% solar conversion efficiency in a tandem cell incorporating both a microcrystalline and amorphous silicon absorber layer. A new manufacturing facility for amorphous-silicon-based tandem solar cells is presently under construction in Virginia, with full production of amorphous silicon multijunction modules on ~ 8 ft.^{2} glass substrates aimed for 1997.

In Symposium B new results on the fundamental properties of dislocations in semiconductor heterostructures include the real-time observation of the motion of dislocation kinks in plastically deformed Si by high resolution transmission electron microscopy and the observation by spatially resolved electron energy loss spectroscopy of changes in the electronic structure of the heterojunction in the vicinity of a misfit dislocation near the interface between a strained Si layer on relaxed SiGe.

A dramatic improvement in the defect density ($1–3 \times 10^3$ cm^{-2} over a 3-in. wafer) of ZnSe-based heteroepitaxial structures for blue-green laser diodes was announced, employing homoepitaxial buffer layers, improved pregrowth wafer handling, Zn irradiation, and migration-enhanced epitaxy on ordered GaAs surfaces. Such defect density reductions are closely tied to improvements in expected laser diode lifetimes.

There was much interest in the wide bandgap nitrides (GaN and related alloys) for short wavelength emitters and high-temperature/high-power electronics in Symposium C, Compound Semiconductor Electronics and Photonics. Of particular interest were new results on dry etching of GaN and other III-V compounds with new inductively coupled plasma sources.

Reports on rare earth doping using molecular beam epitaxy, chemical vapor deposition, and ion implantation as presented in Symposium D, Rare Earth Doped Semiconductors II, indicated that sufficiently high concentrations can now be incorporated in Si as well as III-V semiconductors. The challenge is to efficiently excite the ions, and to reduce the nonradiative processes that quench the luminescence at high temperatures, which requires co-doping with impurities such as oxygen and nitrogen. A demonstration of voice transmission was performed during the symposium using an all-silicon integrated optoelectronic circuit. The Si:Er light-emitting diode driven by an n-channel metal-oxide-semiconductor field-effect transistor produced a frequency response of 20 kHz and showed that it is possible to transmit information optically using silicon, although the particular application was just for show.

While silicon strives to enter the optical race, wide bandgap materials look to find electronic niches in harsh environments that silicon cannot handle. Symposium E, III-Nitride, SiC, and Diamond Materials for Electronic Devices, answered this call. These robust materials have potential to perform in high temperatures, using high power, or when showered with radiation. These materials can lead to improved performance through increased energy efficiency, weight savings through the elimination of cooling hardware, and increased reliability through the reduction of moving parts for applications such as auto and jet engines, direct-drive electric motors, and high-power radio frequency devices for communications and missile systems. A panel discussion addressed the impact of physical defects such as micro- and nanopipes in SiC and GaN, the role that diamond can play, and whether wide bandgap epitaxy is able to meet requirements needed for success. There was disagreement about whether the pipes affect performance, although one suggestion was that defects associated with the pipes play a role. The consensus was that a desirable direction for diamond-based devices was in the area of electron emission. A hand vote of the audience on organometallic vapor phase epitaxial reactor designs for GaN growth favored a vertical, high-speed, low-pressure design; yet, any

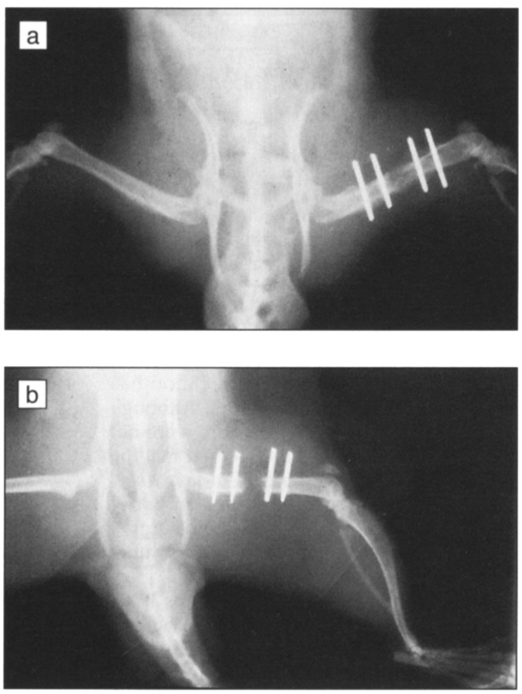
Mikos Gives OYI Presentation on Tissue Engineering

Antonios G. Mikos of Rice University and recipient of the 1996 MRS Outstanding Young Investigator (OYI) Award has been researching the synthesis of biodegradable polymers for bone repair and reconstruction, the use of bone materials for cardiovascular applications, and targeted delivery of genes to injured arteries. In his OYI presentation, "Biomaterials for Tissue Engineering," given as part of Symposium Y on Structure Controlled Macromolecules of Nanoscopic Dimensions, Mikos concentrated on injectable biomaterials to repair skeletal defects, biodegradable materials to engineer bone tissue, and the use of polymeric microparticles to treat an injured artery. The modern direction in biomaterials is to develop materials that act as scaffolds or growth promoters to grow, repair, and work with the body to develop its own tissue.

The disadvantages of current methods of bone tissue treatment, including autograft and bone cement, have led to research for a bone graft substitute which would be biocompatible, not induce an inflammatory response, and would provide an osteoconductive matrix upon which bone tissue can grow. The matrix is to include osteoinductive factors, osteogenic cells, and provide restructuring integrity to the repair area. While no such material is yet available that fulfills these requirements, Mikos has been developing materials in his laboratory.

An injectable biodegradable biomaterial has been developed that holds promise for human trabecular bone repair. Mikos presented several examples of polymer synthesis based on poly(propylene fumarate). The results of animal studies show bone tissue growing into the degrading biomaterial, so that the material behaves in essence as a scaffold that guides tissue growth.

The process of implanting a polymer scaffold seeded with cells, unlike the process of injectable biomaterials, is conducive for reconstructing a skeletal defect, such as after the removal of a tumor for which a piece of the bone is removed. In one example, Mikos explained the use of polymer scaffolds made of co-polymers of lactic and glycolic acid. In his laboratory, Mikos and his collaborators have formed three-dimensional cultures of bone cells providing a template for the development and the reorganization of cells and the formation of new tissue. In the treatment of artery injury, Mikos is developing biomaterial processes that will immobilize bioactive molecules at the site of the injury, which is a difficult task because blood is flowing in the blood vessel. One system involves the use of 50-μm polymeric microparticles that slowly release therapeutic molecules in the appropriate area around the blood vessel. (For more details, look for Mikos's article scheduled for the November 1996 *MRS Bulletin*.)



(a) Radiograph of healing of a long bone segmental defect in a rat six weeks after implantation of a biomaterial carrier for recombinant human bone morphogenetic protein-2 (rhBMP-2) whereas (b) indicates no healing of the same defect for an untreated control.

improved reactor designs need further knowledge of kinetics/dynamics of the GaN growth process.

Particular interest was generated in Symposium F, GeSi and Related Materials, for island growth to produce dots of dimension in the range of 0.01– 0.1 μm. Raman shift measurements of stress in these small structures were strongly affected by stress relief at the edges of the features. Buried oxides were used to form compliant substrates where very thin layers of silicon were strained by the growth of epi layers.

A display based on new suspended particle complexes was presented in Flat-Panel Display Materials, Symposium H, an area showing continued innovation. In Symposium I, Liquid Crystals—From Theory to Application, synthetic approaches featured polymers based on polydienes, the ring opening polymerization of oxiranes and oxitanes, block-liquid-crystal copolymers, photoreactive cholesteric materials, and new fluorinated low molar mass compounds for LCD applications.

Information storage devices, printers, and rechargeable batteries shared the stage in Symposium M, Materials and Processes for Peripheral Microelectronic Devices. Giant and colossal magnetic resistance film stacks were described as potential candidates for future applications for magnetic storage. Durability against wear and corrosion were shown to be important in the selection of new materials for storage and other applications. New lightweight and low-cost composite materials for electromagnetic shielding and their importance in portable computers with wireless communication needs were described. In the batteries area, Ni-metal hydrides and lithium ion batteries are emerging as leaders, but new chemistries are needed for the longer term.

Interest in modeling and temperature control emerged out of Symposium N, Rapid Thermal and Integrated Processing V, which has been gaining industrial attention. The largest use of RTP in manufacturing is for silicides and barriers. Formation of sol-gel films and magnetic recording head applications were considered promising areas for RTP. RTP of dielectrics has generated tremendous research and interest, but is not yet ready for real production. Temperature measurement continues to be an issue, with pyrometry as the most useful technique. One SEMATECH goal in the National Technology Road Map for Semiconductors was to measure temperature changes of +/- 3°C, 10°C across a wafer, and at a cost of 2.5¢/wafer, with the next milestone to see if +/- 2°C is possible.

In Symposium Q, Materials Challenges for Applications of High-Temperature Superconductors, processing techniques using ion-beam assisted deposition and pulsed laser ablation looked promising for high-current applications. Progress toward large-area thin films was evident, for instance, by reactive co-evaporation of constituents, achieving uniform critical current densities of greater than 2×10^6 A/cm^2 at 77 K over an 8-in.-diameter sapphire wafer.

Fiber optics is finding application from structure reliability to chemical sensing. In Symposium R, Fiber Materials for Electronics, Optoelectronics, and Sensors, a researcher reported using a plasma-mechanical deposition process for fiber fabrication. In the chemical sensing arena, porous sol-gel silicate glasses were used to perform a variety of gas monitoring applications.

MRS Meeting attendee Tom Hardek checks the sound and quality of a Nuvo Graphite banjo during Symposium BB on Materials in Musical Instruments. Constructed to be travel friendly, lightweight, with a superior tone and user friendly, the neck of the banjo is made from carbon fiber/epoxy composite and the tone ring/pot assembly is made of a filament wound carbon fiber/epoxy one-piece unit.

Symposium S, Aqueous Chemistry and Geochemistry of Oxides, Oxyhydroxides, and Related Materials, covered the structure and stability of oxide surfaces, colloid chemistry, and reactions including adsorption, surface complexation, precipitation, dissolution, and corrosion. Microporous oxides and oxyhydroxides are being used to develop active elements for batteries, ultracapacitors, and fuel cells. Development of electroactive oxides in a stable, high surface area form has led to the development of commercially viable products.

Symposium Z, Environmentally Degradable Polymers, contained an impromptu discussion on environmentally degradable polymers which stretched across the full field from technical issues to exploration into the lack of current widespread acceptance of environmentally degradable polymers. The general consensus suggested that acceptance will be gradual, beginning in suitable markets where cost/performance is not an issue (e.g., fast food packaging and farm land applications for temporary cover of crops), and, perhaps, water-soluble polymers. Technical approaches were expected to continue in the current direction toward either natural resource modification, starch, cellulosics, or synthetics with structural units similar to polymers found in nature (e.g., polyesters, polyamides).

For the second time a symposium was held on materials in musical instruments, Symposium BB. String and percussion instruments captured most of the attention. Use of synthetic materials such as graphite/epoxy composites for guitars and banjos was balanced by discussion of traditional guitar woods. An evening demonstration provided further opportunity for contrasting synthetic and traditional instruments.

For more on various technical symposia, see the summaries on the following pages and the proceedings volumes.

Amorphous Silicon Spreads to Manufacturing

(See MRS Proceedings Volume 420)

Symposium A, Amorphous Silicon Technology, included joint sessions with Flat-Panel Display Materials (Symposium H) and Thin Films for Photovoltaic and Related Device Applications (Symposium J), reflecting the increased spreading of amorphous silicon to applications. Recent advances in solar cells incorporating microcrystalline silicon absorber layers were described by J. Meier (Universite de Neuchatel); his research group has demonstrated a 13.1% solar conversion efficiency in a tandem cell incorporating both a microcrystalline silicon layer (as the absorber for lower energy photons) and an amorphous silicon absorber layer. The efficiency declines somewhat as the cell is used; the authors attributed this decline entirely to the well-known instability in the amorphous silicon layers of the cells. C. Nebel (Technical Univ. of Munich) described the patterning and texturing of amorphous silicon using pulsed lasers capable of crystallizing the amorphous material. The innovation in this research is to exploit interference effects to create crystallized one- and two-dimensional grating patterns in the amorphous matrix.

In the joint session with Symposium J, L. Yang (Solarex, a business unit of Amoco/Enron Solar) described a manufacturing facility for amorphous-silicon-based tandem solar cells which is presently under construction in Virginia. P.C. Taylor presented work at the University of Utah on amorphous silicon-sulfur alloys, for which the "Staebler-Wronski" instability of conventional amorphous silicon may anneal out at room temperature.

In the joint session with Symposium H, T. Tsukada (Hitachi) described his company's work toward realizing both higher resolution and improved visibility in active-matrix liquid crystal displays. The display research program at Xerox PARC, described by M. Thompson, has stimulated the formation of a company, dpiX, which is manufacturing both high-resolution flat-panel displays and two-dimensional sensor arrays. J. Hautala discussed work at Tokyo Electron America's laboratory on raising the deposition rate for amorphous silicon transistors.

These advances in devices and manufacturing may be further accelerated when several fundamental puzzles regarding amorphous silicon's structure and optoelectronic properties are resolved. R. Norberg (Washington Univ.) suggested that the "broad line" for protons found in nuclear magnetic resonance measurements corresponds to molecular hydrogen; the conventional interpretation, originated by Reimer, Vaughan, and Knights in 1979, holds that this environment consists of clusters of hydrogens, each bonded to silicon.

The Staebler-Wronski effect—the reversible degradation of optoelectronic properties by excess carrier recombination in a-Si:H—has tor-

https://doi.org/10.1557/S0883769400035958 Published online by Cambridge University Press

mented both scientists and device engineers for nearly 20 years. T. Shimizu (Kanazawa Univ.) reviewed many of the current models for this effect, and proposed a possibility of incorporating negatively charged, floating bonds associated with five-fold coordinated silicon atoms. S. Yamasaki (JRCAT-NAIR, Ibaraki) and his colleagues reported new electron paramagnetic resonance experiments which show that carbon and oxygen impurities are not the cause of the Staebler-Wronski effect.

G. Adriaennsens and V. Arkhipov (Univ. of Leuven) introduced a view of charge carrier emission from defects in amorphous silicon, which is that the emission is largely controlled by temporal fluctuations in the defect's energy level. This view should be contrasted with the conventional view, which invokes stationary, spatial inhomogeneities in defect level energies to account for the enormous range of emission rates observed in a-Si:H and related materials. The temporal fluctuation view finds some resonance in the atomistic simulations of R. Biswas and Q. Li (Iowa State Univ.), and also in the observations of $1/f$ noise by J. Kakalios's group at the University of Minnesota.

G. Parsons (North Carolina State Univ.) summarized work done on selected area deposition of silicon thin films using time modulation of silane flow to the plasma; on certain substrates, a silicon film less than a critical thickness can be etched away by a hydrogen plasma, while thicker films become stable. These results indicate the importance of the initial phase of growth of plasma deposited silicon thin films. K. Ikuta presented scanning tunneling microscope images of this initial phase obtained by the JRCAT-NAIR group.

Symposium Support: Materials Research Grp., Fuji, Sanyo, Solarex, UNI-SOLAR, Voltaix, MV Systems, Energy Conversion Devices, Inc., Microchemistry Ltd., EPRI, Sharp, dpiX.

Heterostructure Mismatch Leads to Defects

Applications of lattice-mismatched semiconductor heterostructures for state-of-the-art electronic and optoelectronic devices discussed in Symposium B, Defects and Interfaces in Lattice-Mismatched Semiconductor Heterostructures, included blue-green lasers fabricated from II-VI semiconductors, various quantum structures fabricated with III-V semiconductors, and high-speed field-effect transistors (FETs) utilizing strained Si or SiGe layers on relaxed SiGe buffer layers. Although the dislocations threading through the SiGe buffer layers are electrically active, concentrations are low enough that their effects on low-temperature electron mobility are negligible. Results on the fundamental properties of dislocations include the real-time observation of the motion of dislocation kinks in plastically deformed Si by high-resolution transmission electron microscopy and the observation by spatially resolved electron energy loss spectroscopy of changes in the electronic structure of the heterojunction in the vicinity of a misfit dislocation near the interface between a strained Si layer on relaxed SiGe. Calculations of the modification of the surface morphology of SiGe films due to mismatch strain and resulting compositional variations in the layer were also reported as were calculations of the strain redistribution of both the SiGe film and the Si substrate.

Fundamental issues associated with strain relaxation mechanisms and interface roughness were addressed in many of the talks on III-V materials. The usefulness of high-resolution x-ray diffraction techniques including both topography and reciprocal space mapping for evaluating the quality of epitaxial layers and for the study of strain-relieving defects was demonstrated. *In situ* x-ray topography was carried out during molecular-beam-epitaxy growth of InGaAs/GaAs heterostructures at a synchrotron source. By correlating the x-ray images with localized transmission electron microscopy images the nature of the misfit dislocation sources at the interface as a function of epilayer thickness was determined. Linearly polarized cathodoluminescence imaging was applied to the study of III-V semiconductor heterostructures. Local variations in excitonic polarization anisotropy, emission energy, and activation energy are found to correlate spatially with dark-line defects in the material. Investigations of interface uniformity using cross-sectional scanning tunneling microscopy was described.

A dramatic improvement in the defect density of ZnSe-based heteroepitaxial structures for blue-green laser diodes was announced. Employing a combination of homoepitaxial buffer layers, improved pregrowth wafer handling, Zn irradiation, and migration-enhanced epitaxy on $c(4 \times 4)$ ordered GaAs surfaces, the etch pit density of $1–3 \times 10^3$ cm^{-2} over a 3-in. wafer was achieved. Such defect density reductions are closely tied to improvements in expected laser diode lifetimes. Dramatic improvements in ZnCdSe epilayers on InP were also achieved by optimizing initial growth and substrate preparation procedures. A mechanism for the degradation of ZnSe-based heteroepitaxial diode laser structures based on the emission of a cluster of vacancies from Frank-type stacking faults, leading to strain generation of small dislocation loops and the formation of dark-line defects was proposed.

Symposium Support: Philips Electronic Instruments, Blake Industries, IBM Analytical Services, Xerox Wilson Center for Research & Technology, Charles Evans & Assoc., Bede, ONR.

Development Seen for Applications of Compound Semiconductors

(See MRS Proceedings Volume 421)

Symposium C, Compound Semiconductor Electronics and Photonics, was the latest in a long series of symposia held at MRS meetings on the growth, characterization, and processing of III-V semiconductors. The combined maturation of compound semiconductors for applications in metal-semiconductor field-effect transistor (FET), high electron mobility transistor, and heterojunction bipolar transistor (HBT) discrete devices and circuits, and for photonic devices such as light-emitting diodes, vertical-cavity surface-emitting lasers (VCSELs) and modulators, was clearly evident in this meeting. There was much interest in the wide bandgap nitrides (GaN and related alloys) for short wavelength emitters and high-temperature/high-power electronics. Of particular interest were results on dry etching of GaN and other III-V's with inductively coupled plasma sources, highlighted in papers by C. Constantine (Plasma Therm) and R.J. Shul (SNL). Continued development of electron-cyclotron-resonance etching processes was covered by J.R. Flemish (Ft. Monmouth) and F. Ren (Lucent Technologies), while all-implanted junction FET structures produced at Sandia by J.C. Zolper and A.G. Baca attracted much interest. New directions in lightwave communication and high-power lasers were covered by F.R. Shepherd (BNR) and D.F. Welch (SDL). The reliability of lasers for data and voice transmission is a major concern, and was covered in an overview talk by S.N.G. Chu (Lucent Technologies). A lot of interest remains in III-V surface passivation (reviewed by M. Passlack of Motorola), design and operation of VCSELs (R.P. Schneider of HP, K.D. Choquette of SNL), epitaxial growth (E.A. Beam III of TI), HBTs (G.P. Li of UC—Irvine), and band-structure engineering (H. Shen, Ft. Monmouth). Strain effects in GaN-based lasers were covered by M. Suzuki (Matsushita) while ion implantation of GaN was reviewed by J.S. Williams (ANU).

Symposium Support: ARO.

Co-Doping with Impurities Heighten Capabilities of Rare Earth Ions to Serve Semiconductors

(See MRS Proceedings Volume 422)

The second MRS Symposium on Rare Earth Doped Semiconductors, Symposium D, held three years after the first one, was an international meeting with 54 contributions from 18 countries. Research on rare earth doped semiconductors is mostly motivated by internal transitions in the rare earth ions that can be used to obtain well-defined and temperature-independent optical emission from these semiconductors. For example, in Si, which does not emit light due to its indirect bandgap, doping with erbium can lead to emission at 1.54 μm, an important telecommunication wavelength.

The symposium topics included growth mechanisms; structural, electrical and optical properties; excitation mechanisms; as well as electroluminescence and integration. Reports on rare earth doping using molecular beam epitaxy, chemical vapor deposition, and ion implantation indicated that sufficiently high concentrations can now be incorporated in Si as well as III-V semiconductors. The challenge is to efficiently excite the ions, and to reduce the nonradiative processes that quench the luminescence at high temperatures. Co-doping with impurities such as oxygen and nitrogen has been shown to be essential to achieve this. In a lively discussion session, an attempt was made to put all reports on impurity-related effects in a coherent perspective. Some impurities serve to increase the effective solubility of the rare earth dopants, reduce the luminescence quenching, and increase the electrical quality of the host material. Optimized Si and GaP diodes that were presented have an internal quantum efficiency in the 0.01% range. Several ideas were presented which may help to achieve a further 100-fold increase in the efficiency that is required for practical application of rare earth doped semiconductors.

Symposium Support: High Voltage Engineering Europa, C.Ri.M.Me, CNR, ARO.

GaN, SiC, Diamond Find Electronics Niche

(See MRS Proceedings Volume 423)

Over 140 papers were presented in Symposium E, III-Nitride, SiC, and Diamond Materials for Electronic Devices. In addition, an early evening panel discussion was held that reached a consensus that electron emission from diamond-based devices was a desirable direction to take for that technology. The effects of nanopipes on SiC and GaN devices were also discussed. Organometallic vapor phase epitaxial reactor designs for GaN growth were discussed and many in the audience favored a vertical, high-speed, low-pressure design; yet, until essential information about the kinetics/dynamics of the GaN growth process becomes available, improvements in current reactor designs may be difficult.

R.J. Trew (CWRU) started the Symposium with a review of wide bandgap semiconductor amplifier devices. He noted that GaN field-effect transistors (FETs) have performance similar to the more established 4H SiC for frequencies less than 10 GHz, the range predominantly studied to date, probably because of the similarity in mobility for a given electron concentration in the two materials. L. Rea (Wright) said that motivations for wide bandgap technology research are connected to the important role high-power/high-frequency electronics would have on Department of Defense avionics in the near future and described some of the challenges that electronic materials must meet to address these applications. S. Binari (NRL) presented GaN-based FET performance data. The metal-semiconductor FET (MESFET) and metalorganic decomposition FET (MODFET) data fall into two groups (with MODFET as the better performer) with f_T approximately following the expected inverse gate length functional dependence.

R. Rupp (Siemens) described how the important progress made in 6H SiC epitaxy has resulted in unintentionally doped epitaxial layers with electron concentrations in the low 10^{14} cm^{-3}. Efforts on halide vapor phase epitaxial growth of GaN were reported by T. Kuech and co-workers (Univ. of Wisconsin), R. Molnar and co-workers (MIT), and J. Harris and co-workers (Stanford), and the properties of these materials were fast approaching those of epitaxial films grown on sapphire. Epitaxial InAsN lattice matched to GaAs was reported by Y. C. Kao (TI). Recent NEA results on diamond and AlGaN were reported by C. W. Hatfield and P. K. Bauman (NCSU).

Other presentations dealt with the issues of metalizations and dry etch processing of these wide bandgap semiconductors. Another theme was the role hydrogen plays in these semiconductors.

Symposium Support: ARO, ONR, Grumman-Northrup, Rockwell Int'l, Kobe Steel USA.

Oxidation of GeSi Generates Much Research

Particular interest was generated in Symposium F, GeSi and Related Compounds, for island growth. Geometries were typically in the range of 0.01–0.1 μm. Dots formed this way were characterized optically, as well as with atomic force microscopy and transmission electron microscopy.

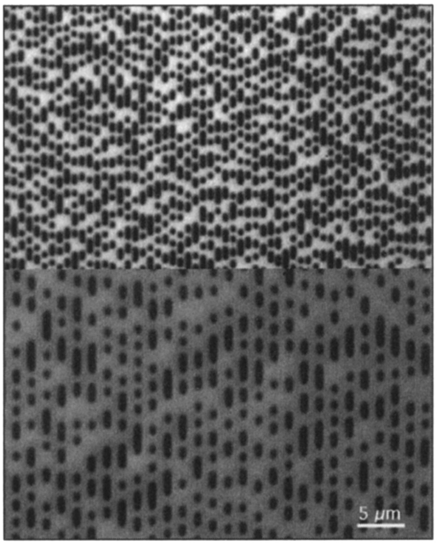
Reviews for the Nonspecialist: Information Storage

A series of five lunchtime presentations revolved around the theme of materials for information storage. Symposium X, Materials Challenges in Information Technology, included talks on magnetic storage media and head materials (R. Ranjan of KOMAG, Inc. and R.M. White of CMU, respectively), photographic imaging (J. Rodgers of Eastman Kodak Co.), optical recording (M.B. Hintz of 3M Co.), and holography (D. Psaltis of California Institute of Technology). All of the technologies bring in a data signal, write it onto a material by locally changing the material—be it by shape, chemistry charge distribution, magnetization, or structure—then read out the data by sensing the local variation. Each technology, however, relies on a different set of materials parameters, processing schemes, and sensing methods, facing a different set of challenges.

Holography gained popularity in the 1960s and 1970s, but did not take off due to lack of suitable materials. While materials are still an issue, the last five years have brought renewed interest to this area since other problems seem solvable. While thousands of materials have been tested, currently two are considered practical: a 100-μm-thick copolymer film from DuPont (DuPont HRF-150) and photorefractive crystals, particularly Fe-doped lithium niobate ($LiNbO_3$:Fe).

Holographic storage is based on recording the interference of two laser beams—an object beam encoded with input data and a second coherent reference beam—within the volume of a material. Changing the angle of the beam allows independent recording of multiple data pages that can be independently read by changing the angle of the readout beam.

One of the challenges of holographic technology is finding a way to "fix" the data to prevent decay when it is read. One method to resolve the problem is electrical fixing in which ferroelectric crystals are used to create a space-charge grating. The local polarization state of the material is not sensitive to light, so a fixed grating is produced. To rewrite, a positive field repoles the entire crystal.



A comparison of current CD optical disk density (bottom) with a prototype high-density format (top).

Ferrites were the first broadly used materials for magnetic recording heads, particularly because of this material's resistivity property. Magnetic heads magnetize a material to write, which is influenced by saturation induction of the head material. In 1988, giant magnetoresistance (GMR) was discovered which can be used in fields of 10 Oe and at room temperature, whereas low temperature and very high fields were previously needed. These materials are expected to appear in the next generation of heads, in just a few years.

Thin film sputtered media for hard disk drive technology has become the medium of choice for magnetic storage. Research in this area is challenged with the need to support the areal density growth. The head-to-medium spacing (flying height) has to be decreased to minimize the spacing loss in order to support higher areal density. Among other needs, this requires new texturing schemes. Pulsed laser texturing, which produces a regular pattern of sombrero-shaped rough spots, is one solution.

Magnetic storage is combined with conventional photography to form the latest in photographic film development known as Advanced Photosystem. The film has visual information on one side of the film, while magnetic information is stored on the other side using nearly transparent magnetic particles as the storage medium.

Insoluble microcrystals of silver halide (generally AgBr), the basic imaging elements in photography, are formed by reaction of a soluble silver salt with a soluble halide salt. Gelatin is used to keep crystals separated during growth. In the last 10 years, tabular crystals have been created which have two or more parallel twin planes within the crystal, which increase the surface-to-volume ratio for light capture.

Major changes have occurred recently in optical recording, including explosive growth of CD-ROM, the battle between different formats for the future multimedia disk, the rapid growth of the write-once CD, the sharply increased interest in erasable phase-change systems, introduction of higher capacity magneto-optic products, and the research demonstrations of short wavelength semiconductor laser diodes which promise high storage densities by defining smaller bits with the laser. Optical disk signals are phase-modulated for CDs, polarization-modulated for magneto-optic systems, and reflectance-modulated for phase change and dye systems. Phase change systems rely on recording data as amorphous bits, which have reduced reflectance.

For more details on photographic technology, see "Film as a Composite Material" in this issue of *MRS Bulletin*, and look for the September 1996 *MRS Bulletin* for more on other types of information storage.

Raman shift measurements of stress in these small structures were strongly affected by stress relief at the edges of the features. A number of authors used this fact to grow pure Ge dots on silicon substrates. The defect density of strain relaxed layers was found to have significant effects on the inversion layer mobility in field-effect transistors. Low temperature mobilities of approximately 300,000 were observed in modulation doped layers. There were reports of *P*-channel devices with f_Ts in excess of 70 GHz. Buried oxides were used to form compliant substrates where very thin layers of silicon were strained by the growth of epi layers. Thick stable layers can be grown in this manner, but are subject to limitations of producing uniform, very thin silicon layers on a buried oxide.

The oxidation of single crystal GeSi builds up an experimentally observed germanium rich layer which eventually slows the oxidation rate. The addition of NF_3 increases the oxidation rate without significant fluorine incorporation. Polycrystalline GeSi oxidation is controlled by Ge grain boundary diffusion. The diffusion of a variety of dopants in GeSi are significantly affected by the strain modulated vacancy concentration.

Both chemical vapor deposition and molecular beam epitaxy growers were able to incorporate maximum concentrations of approximately 2% of carbon in GeSi without the formation of SiC. Each percent of carbon compensates the strain caused by approximately 9% of germanium. Although an increase in the bandgap of strained layers was observed, the rate of increase was much less than the rate of strain decrease.

Symposium Support: ONR.

Liquid-Crystal-Based and Emissive Displays Show Advances
(See MRS Proceedings Volume 424)

The Flat-Panel Display Materials symposium (H) covered advances in materials and devices in a wide range of flat-panel display technologies. In liquid crystal displays (LCD), S. Naemura (Merc Japan) described progress in fluorinated twisted nematic LC materials. A display based on new suspended particle complexes was presented by H. Takeuchi and co-workers (Toyota Motor Corp.). D. Pribat (Thomson CSF) presented recent advances on polysilicon thin film transistors while A. Mimura (Hitachi) described a doping method suitable for the manufacturing of polysilicon thin-film transistor-LCDs (TFT-LCDs). Three separate studies from researchers from Seoul National University and Lehigh University reported high-density plasma oxidation processes for growing the gate dielectric in polysilicon TFTs. High performance TFTs in amorphous silicon deposited at high rates were reported by T. Li and co-workers (Univ. of Michigan and Optical Imaging Systems). A fabrication approach for amorphous silicon TFTs using only sputter deposition was reported by C. McCormick and co-workers (Univ. of Illinois). A sputter deposition process was described by W. Anderson and co-workers (SUNY—Buffalo) for preparing large grain polycrystalline silicon at low temperatures.

Significant advances were also reported in emerging emissive display technologies. C. Tang and co-workers (Eastman Kodak Co.) reported low-power, long-term stable organic electroluminescent displays. M. Slusarczuk described advantages of high voltage field emission displays while R. Ginerich (GTE) said that phosphor for such field-emission displays is now commercially available. Developments in electroluminescent phosphors were presented by B. Wagner (Georgia Tech.), while rare earth doped nanocrystalline phosphors was reported by E.T. Goldburt and co-workers (Nanocrystals Tech.).

Symposium Support: Sharp Microelectronic Technology Inc., Lehigh Univ./Display Research Lab.

Polymers, Elastomers, Composites Join Ranks of LCs
(See MRS Proceedings Volume 425)

Liquid crystalline (LC) materials have found use in many areas of technology and their scope has been extended with the development of liquid crystalline polymers, elastomers, and composite systems. Considerable basic and applied research is being carried out in these areas as was recognized in Symposium I, Liquid Crystals for Advanced Technologies, which presented an opportunity for researchers in different areas to come together, pool resources, and discuss common problems. Synthetic approaches were featured in two half-day sessions which included polymers based upon polydienes, the ring opening polymerization of oxiranes and oxitanes, block-LC copolymers, photoreactive cholesteric materials, and fluorinated low molar mass compounds for LCD applications. A number of presentations throughout the program also centered on the development of glass-forming, low-molecular-weight liquid crystals and their utility in both display and optical applications. Considerable work on polymer-dispersed LC composites was also represented by two half-day sessions highlighting progress in the understanding of switchable scattering films and diffractive gratings formed by a number of phase separation processes. Sessions on display and optical applications of these LC-based compounds, modeling, rheology, chiral smectics, thermosets, and processing techniques were complemented by over two dozen posters in the evening session.

Symposium Support: Chisso Corp., Elsevier Trends Journals.

Graduate Student Award Finalists

During an awards ceremony on Monday night at the 1996 MRS Spring Meeting, eight graduate students were honored with the Graduate Student Award (see photo below) for their academic achievements and outstanding performance in the conduct of their research projects.

Other graduate students honored as finalists were Andrew E. Bair (Arizona State University), Wen-Yen Chang (Washington State University), Devin Crawford (University of Minnesota), Mani Gopal (Lawrence Berkeley National Laboratory), Patrick N. Grillot (Ohio State University), Alfonso Ribes (University of Waterloo), Kirill Rybakov (Johns Hopkins University), Anthony St. Amour (Princeton University), Weitung Wang (University of Wisconsin), and Marcus Weck (California Institute of Technology). All of the students presented their papers at the various symposia.

The deadline for the completed application for the Graduate Student Award for 1996 MRS Fall Meeting/ICEM-96 in Boston (December 2–6) is **October 21, 1996**. Each award will consist of a cash grant of $250, a plaque which will be presented at the Plenary Session during the meeting, and a waiver of the meeting registration fee. Information and application forms can be obtained from John B. Ballance, Executive Director, Materials Research Society, 9800 McKnight Road, Pittsburgh, PA 15237-6006; 412-367-3003; fax 412-367-4373.

Graduate Student Award recipients (from left to right) Randy-David B. Grishaber (University of California—Davis), "Mechanical Behavior and Constitutive Modeling during High-Temperature Deformation of Al-Laminated Metal Composites"; C. Allan Guymon (University of Colorado), "Polymerization Effects on the Electro-Optic Properties of a Polymer Stabilized Ferroelectric Liquid Crystal"; Paul G. Clem (University of Illinois—Urbana), "Micron Scale Patterning of Solution Derived Ceramic Thin Films Directed by Self-Assembled Monolayers of Octadecyltrichlorosilane"; Christopher O. Oriakhi (Oregon State University), "Displacement of Polymers from Layered Nanocomposites via Ion Exchange"; Holly Claudia Slade (University of Virginia), "Below Threshold Current Distribution in a-Si:H Thin Film Transistors (TFTs): Back Channel Conduction"; John T. Chen (Massachusetts Institute of Technology), "The Morphology Diagram of a Poly(styrene-b-hexyl isocyanate) Rod-Coil Block Copolymer"; Tristan Haage (Max-Planck-Institut für Festkörperforschung), "Tailoring the Microscopic Defect Structure in $YBa_2Cu_3O_{7-\delta}$ Thin Films"; and Doug Rose (University of Colorado), "The Effect of Oxygen during Close-Spaced Sublimation (CSS) of CdTe Solar Cells."

https://doi.org/10.1557/S0883769400035958 Published online by Cambridge University Press

Photovoltaic Efficiencies Top 17% in Europe, Japan, U.S.

(See MRS Proceedings Volume 426)

Symposium J, Thin Films for Photovoltaic and Related Device Applications, covered a broad spectrum of advances in photovoltaics materials and devices. J. Tuttle and co-workers (NREL) reported record sunlight-to-electricity efficiencies of 17.7% both under one-sun illumination and under 20× concentration from thin-film photovoltaic devices based on $Cu(In,Ga)Se_2$ (CIGS). T. Negami and co-workers (Matsushita Electric Industrial Co.) reported on innovative film composition monitoring methods based on near infrared transmittance, reflectance, and dynamic film temperature, and showed 17% efficient CIGS solar devices produced using these control methods. These reports mean that thin-film CIGS solar cells of ca. 17% efficiency have been achieved in the United States, Japan, and Europe (e.g., by the collaboration of H. Shock and co-workers of the Institute of Physical Electronics and L. Stolt and co-workers of Royal Institute of Technology), underscoring the promise of this class of materials for photovoltaics applications.

Other significant innovations reported included the silicon parallel multilayer thin film solar cell of M. Green and co-workers (Univ. of New South Wales) and the formation of thin-film CdTe solar devices from nanoparticle precursors reported by D. Schulz and co-workers (NREL). The silicon parallel multilayer cell structure seeks to overcome the transport limitations of thin-film silicon materials by combining optical light trapping and thin *pn* junction stacks (e.g., 3–13 thin-film *pn* junctions in a stack ca. 10 μm thick) such that photogenerated charge carriers are collected before being lost to recombination at grain boundaries and other layer defects. Green predicts that 15% efficiencies can be obtained from thin-film Si on substrate cells using low quality silicon with lateral grain sizes as small as 5 μm. NREL's work on nanoparticle-derived CdTe combines the preparation of methanol-capped CdTe colloids (e.g., of 2.5–7.5 nm diameters) and simple spraying of a colloidal suspension onto a heated substrate to form dense CdTe films suitable for solar cells. The use of methanol-capped CdTe formed by reacting cadmium iodide with sodium telluride in a methanol solvent resulted in substantially less residual carbon contamination in the final CdTe films relative to that earlier found for trioctylphosphine- (TOP) and trioctylphosphine oxide- (TOPO) capped CdTe nanoparticles.

Symposium Support: Corning, Siemens Solar Industries, Exxon.

Metallization Road Map Continues Trend Toward Smaller Features

(See MRS Proceedings Volume 427)

At Symposium K on Advanced Metallization for Future ULSI, T. Seidel (Genus) and D.B. Fraser (Intel) presented the national technology road map for metallization. The minimum feature size in production now is 0.35 μm with 0.25 μm scheduled for 1997 and 0.18 μm for the turn of the century. Currently, four layers of Al metals with W plugs are used with five layers planned for 1997 and six layers by 1999. For logic devices there is 0.84 km of metal lines, which will increase to 2 km by 1999. The cross-sectional views of the metallization structure shown were stunning with the observation that up to 20 chemical compounds comprise a multilevel metallization stack whereas only two compounds (Al and SiO_2) were common a few years ago. L.J. Chen (Nat'l Tsing Hua Univ.) said that logic technology drives metallization.

For silicon technology, the use of copper for local interconnects and the importance of ultrathin diffusion barriers were frequently discussed. S.P. Muraka (Rensselaer Polytechnic Institute) presented a fully-attended workshop on chemical-mechanical polishing.

One of the sessions was held jointly with Symposium L on Materials Reliability in Microelectronics, highlighting the area of electromigration and thermal stability. Sessions on contacts to Si featured silicides (as well as salicides) and other sessions emphasized dielectrics, diffusion barriers, patterning, and via plugs.

Symposium Support: Applied Materials, Vanguard Int'l. Semiconductor Corp., Taisil Electronic Materials Corp., United Microelectronics Corp.

Electromigration Research Drifts to Oxide Reliability

(See MRS Proceedings Volume 428)

The sixth annual symposium on Materials Reliability in Microelectronics (Symposium L) presented developments in the traditionally strong area of electromigration in integrated-circuit (IC) interconnects. Progress in understanding electromigration was clearly illustrated by the juxtaposition of a historical session (see "'Grand Masters' Characterize Early Years of Electromigration") and sessions dealing with current topics. Nearly a full day of well-attended talks on oxide reliability attested to the growing importance of this area in the symposium. Sessions on stress effects and stress measurement techniques also brought several developments and described the progress in making spatially resolved stress measurements on a single IC interconnect.

The extent to which the study of electromigration in IC interconnects has moved beyond its historical engineering roots to embrace materials issues was illustrated by a number of modeling papers and papers reporting detailed observations of microstructural evolution. The dynamics of electromigration void motion and shape change was the subject of a paper by O. Kraft, U. Möckl, and E. Arzt (Max-Planck-Institut für Metallforschung), who numerically simulated a variety of observed phenomena by accounting for diffusion along void surfaces. They showed that voids with fast diffusion paths available were stationary and wedge-like, while those with slower diffusion paths available tended to move and become slit-like; for slowly growing voids, shape change can have a significant effect on conductor lifetime. They were also able to show that the observed faceting of voids is not caused by surface tension anisotropy, but rather by surface diffusivity anisotropy.

The defects responsible for intrinsic breakdown in metal-oxide-semiconductor oxides received an extensive review by T. Oldham (ARL), who said that work on radiation effects had led to an understanding of oxide defects created during manufacturing.

Spectroscopic studies, including those reported by J. Conley (Dynamics Research Corp.), have identified the structure and bonding of these defects and their role in charge trapping. A trio of papers by J. Lagowski and co-workers (Univ. of South Florida and Semiconductor Diagnostics, Inc.) described fast, noncontact, tools for assessing oxide integrity. These tools produce whole-wafer maps of plasma damage, mobile charge, and iron contamination. In contrast with more established techniques, they do not require special test structures.

Several sessions, including a joint session with Symposium CC on Thin Films: Stresses and Mechanical Properties, dealt with the role of mechanical stress in interconnect reliability. A paper by R. Gleixner and W. Nix (Stanford) examined the difficult and neglected issue of stress void nucleation (as opposed to growth) in passivated interconnects. While classical kinetics shows that void nucleation at a clean metal/passivation interface is unlikely, they demonstrated that the presence of patches of contamination at the interface can allow the metal surface to bow sufficiently in response to stress to nucleate a void. Beyond a critical stress, transport-limited growth of the void takes over. E. Chason and J. Floro (SNL) described an *in situ* wafer curvature technique to measure thin-film stresses in real time during deposition, a technique that is easily added to existing deposition equipment. This technique maps wafer stress in two dimensions without scanning. They have applied it, as an example, to study strain relaxation during epitaxial growth of SiGe on Si. The growing importance of understanding stress effects at the microstructural level was emphasized by M. Marcus (AT&T) and I. Noyan (IBM), who separately presented progress reports on the emerging ability to make microbeam x-ray stress measurements on a submicron scale.

Symposium Support: SNL, Advanced Micro Devices, Digital Equipment Corp., Aetrium/Sienna Technologies, AT&T Bell Labs., SEMATECH, Philips Semiconductors, LLNL, AT&T Microelectronics, IBM T.J. Watson Research Center, Materials Research Corp., Tencor Instruments Corp., TI.

Storage Devices, Printers, Batteries Support Microelectronic Devices

Symposium M on Materials and Processes for Peripheral Microelectronic Devices focused on issues relevant to storage devices, printers, and rechargeable batteries. Because of the broad coverage of subjects involved, a good fraction of the talks were reviews presented by researchers in the forefront of the particular area. Speakers from universities and industry participated, providing a balanced view from the research as well as technology status viewpoints.

Speakers on magnetic recording (M.H. Kryder of CMU and M.A. Russak of HMT Tech.) stated that the storage densities are increasing from 1 $Gbit/in^2$ in manufacturing today to future levels 10- to 100-fold higher. Magnetoresistive and giant magnetoresistive (GMR) materials and technologies will be the key enablers of these increased density levels. New materials as well as multilayer thin film stacks were described that have potential for achieving the desired micro-

https://doi.org/10.1557/S0883769400035958 Published online by Cambridge University Press

structure and properties required for these future needs. J. Brug (HP) reviewed activities on giant and colossal magnetic resistance film stacks which are potential candidates for these future applications and alluded to layered unit cell materials as the extension of deposited stacks. Head/disk tribology effects were discussed and compared with computer models of the interface processes by C.G. Harkins (HP) pointing to new ways one can tailor these interfaces for superior durability. G.S. Frankel (Ohio State Univ.) described the corrosion issues in storage devices and stressed the need to include corrosion resistance as one of the key criteria in selecting new materials for future applications rather than make it an afterthought. Several papers described the ongoing activity in the field with a significant tilt toward GMR materials. A. Pan (HP) reviewed the materials issues in the harsh chemical and thermal environments of the ink jet print heads, the work horse of low-cost printing. He outlined the challenges in achieving and maintaining consistent volumes and velocities for the ever decreasing sizes of ink droplets required for higher resolution ink jet printing. Lightweight and low-cost composite materials for electromagnetic shielding and their importance in portable computers with wireless communication needs were described by D.D.L. Chung (SUNY—Buffalo). In the batteries area, D.W. Murphy (AT&T) said that although Ni-metal hydrides and lithium ion batteries are emerging as leaders, new chemistries are needed for the longer term. Lithium ion battery status was reviewed by J.M. Tarascon (Univ. de Picardie Jules Verne, Amiens, France) and new materials issues were addressed by Chung. Materials and technology issues related to the thin, lightweight lithium batteries used in the expanding market for smart cards was described by T. Kalnoki-kis (Gould Electronics). The symposium concluded with a few research papers on materials and processing aspects of materials used in lithium batteries.

Symposium Support: Gould Electronics Inc., IBM T.J. Watson Research Center.

Modeling and Temperature Control Key to RTP

(See MRS Proceedings Volume 429)

In the Rapid Thermal and Integrated Processing (RTP) symposium (N), modeling and temperature control seemed to generate the most interest. The symposium began with a session on equipment issues and modeling. P. Timans (AG Assoc.) reviewed the basics of RTP issues in his invited talk. Two papers gave a review of the SEMATECH RTP work. The session continued with several papers on modeling from the United States and Europe. R. Singh (Clemson Univ.) reminded everyone at the start of the session on annealing that the "thermal" in RTP should include photo effects as well as thermal effects. Other papers in this session discussed real production applications and issues for rapid thermal annealing in both integrated circuit and solar cell manufacturing. The third session focused on RTP applications in silicides and barriers which is the largest single use of RTP in manufacturing.

Papers on temperature control indicate that the ultimate solution does not appear to be available yet, but it is very close. A paper from SEMATECH described the work done in several aspects of RTP as well as the related (or maybe competing) area of fast ramp vertical furnaces. Other papers discussed effects of patterns on wafers and new characterization techniques. One session covered the area of rapid-thermal chemical-vapor-deposition (RTCVD) of silicon and silicon germanium.

In the session on novel RT processes, R. Van de Leest (Philips Research) described the use of RTP for the formation of sol-gel films and F. Roozeboom (Philips Research) described the use of RTP for magnetic recording head applications. Both of these are potentially large applications and a promising area of research. The area of dielectrics (SiO_2 and various combinations of nitride oxides) generates tremendous research and interest, but it does not seem ready for use in real production. The papers indicate that rapid-thermal oxidation and RTCVD oxides are getting close to the quality needed for manufacturing.

Although several papers were from universities, there seems to be a trend toward more work in this field by industry. The field of RTP seems to be maturing with more focus on the manufacturing and process control, but work in nontraditional areas is also apparent.

Symposium Support: CVC Products Inc., Dainippon Screen Mfg. Co. Ltd., Mattson Technology, AG Assoc., AST Elektronik USA Inc., ASM Europe.

Pores Exploited in Molecular Sieves, Zeolites

(See MRS Proceedings Volume 431)

The past several years have seen explosive growth in research on both microporous and mesoporous molecular sieves. In accord with this interest, Symposium P on Microporous and Macroporous Materials covered major advances in synthesis, characterization, and exploitation of the possible mechanisms of formation of porous materials. The symposium opened with sessions on synthetic approaches to zeolites, pillared materials, sol-gel materials, and mesoporous materials. J. Brinker (Univ. of New Mexico) spoke on ambient routes to controlled porosity silicates, including nonhydrothermal syntheses. Several methods to control porosity were given including organic derivatization of silica gel surfaces, use of organic templates, and capillary stress control. Of particular note, K. Balkus (Univ. of Texas—Dallas) described the synthesis of metal substituted UTD-1, a new zeolite in which pentamethylcobaltacinium cation has been used to template the structure. Although complete details of this structure were not given, it was hinted that this material may be the first zeolite with a *larger than 12 T-atom ring*. New types of microporous materials were described including the preparation of microporous metal-organic solids which have both organic and inorganic building units in the structure (O. Yaghi, Arizona State Univ.)

A large number of papers were dedicated to the area of mesoporous molecular sieves. Creative synthetic methods in this area have allowed designed tailoring of composition, pore size, structure, and texture. New mesoporous compositions were described including hexagonal, transition metal oxide structures (J. Ying, MIT). Such compositions may have catalytic uses. The concept of "supramolecular templating" with organic aggregates, proposed as a key mechanistic step in the formation of mesoporous materials, was extended to produce a variety of new materials, for example, lamellar silicas produced with vesicular surfactant assemblies (P. Tanev, Michigan State Univ.). Other sessions in the synthetic area focused on films of inorganic materials. To complement the synthetic areas, several papers on advanced characterization techniques were given, including techniques for studying porosity, as well as advanced spectroscopic techniques.

Deposition Processes Improve Superconductor Properties

In Symposium Q, Materials Challenges for Applications of High-Temperature Superconductors, progress was reported on several fronts in both ion-beam assisted and large area deposition processes. A. Goyal (ORNL) announced that they have coated rolled Ni tapes with the high-temperature superconductor $YBa_2Cu_3O_7$ (YBCO) using pulsed laser ablation. The tapes show critical current densities of 10^5 A/cm^2 at 77 K, making them attractive for high current applications. H. Kinder (Technical Univ. of Munich) reported on progress in the growth of large area thin films of YBCO by reactive co-evaporation of the three cations, along with a unique oxygen pocket radiative heater which allows double-sided deposition. Maps of the local critical current density over an 8-in. diameter sapphire wafer showed uniform critical current densities of greater than 2×10^6 A/cm^2 at 77 K. Progress was also reported by a number of groups on the integration of oxide superconductors and ferroelectrics, including the use of dc voltage-tuned microwave filters for PCS applications (R.E. Treece, Superconductor Core Technology, Inc.).

The graduate student award recipient of Symposium Q, T. Haage (Max-Planck, Stuttgart), presented his work on tailoring the microscopic defect structure of YBCO thin films. By growing films on vicinal cut substrates of $SrTiO_3$, he could encourage step flow growth and introduce translational boundaries in the film between adjacent YBCO unit cells. The films were prepared by pulsed laser ablation and both the substrates and films were studied by scanning tunneling microscopy, cross-sectional transmission electron microscopy, and the film critical currents were determined by the magneto-optical Faraday effect.

Symposium Support: Electric Power Research Institute, ANL, ORNL, LANL, ONR.

Optical Fibers Find Traditional and Innovative Uses

The advent of silica-based fiber optics over the last 20 years has led to an explosion in the performance, reliability, and accessibility of optically-based information services. The use of fiber optics has matured beyond its original ground-based implementation and is finding application in wide-ranging fields from structure reliability to chemical sensing. Symposium R on Fiber Materials for Electronics, Optoelectronics, and Sensors focused on discussions of these topics in addition to the more traditional fiber fabrication issues. Of note in the fabrication arena is the work

"Grand Masters" Characterize Early Years of Electromigration

Six of the original discoverers of electromigration as a reliability issue participated in an historical session on their favorite research subject. James Black, Ilan Blech, P.B. Ghate, Paul S. Ho, Rolf Hummel, and R. Rosenberg congregated for an inspiring morning as they reenacted the first 30 years of electromigration studies.

Black, while at Motorola in the late 1960s, was instrumental in the initial description of the electromigration failure mode. Much speculation at the time depicted that the "cracked stripe" phenomena would bring the industry to its knees. In these studies, Black discovered what has become known since as "Black's Equation" or "Black's Law." In this famous expression the electromigration-related lifetime of a thin film conductor stripe is thermally activated and inversely proportional to the square of the current density:

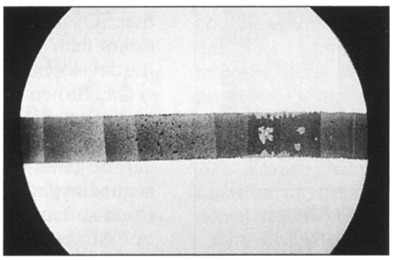
$$t_{50} = Aj^{-2}\exp(\Delta H/kT).$$

Besides this equation, such important concepts as the effect of grain size, passivation, and line width were investigated in this early work, subjects researchers are still studying today. Black was also instrumental in the study of thermal and electromigration-induced failure in Al contacts, leading to the almost universal use for a number of years of Al/Si alloys.

Early pioneers in electromigration—front row, left to right: Ilan Blech, R. Rosenberg, James Black, Rolf Hummel, P.B. Ghate, and Paul S. Ho—provided a morning session on the 30-year history of their field. Back row: Carl Thompson (MRS president), William F. Filter (co-organizer of Symposium L on Materials Reliability in Microelectronics), J. Joseph Clement (co-organizer of Symposium L), J. Lloyd (Chair of Session L3 on Electromigration: A Grand Masters' Perspective).

Second on the podium, Ilan Blech, was probably the first to recognize that electromigration was responsible for the open circuit failures found throughout the industry at the time of its discovery. His earliest work was at Fairchild in 1965 where he showed that certain "zapped" transistors were not classically zapped but that the observed failures were due to some other mechanism. After hearing a talk by H.B. Huntington (then of Rensselaer Polytechnic Institute), Blech believed the mysterious failures may have been due to electromigration and produced a critical experiment that showed this. At the same time, independently, Chabhra and Ainslee at IBM came to similar conclusions. Blech's first paper on the subject was published in 1966.

While working for several American companies in his "spare time" and as a professor at the Technion in Israel, Blech performed some of the most important experiments in electromigration science. One of these was his famous movie of electromigration damage observed with a transmission electron microscope. The film, viewed at the symposium, showed the voids grow, move, heal, and link up to form failures.



TEM micrograph, taken in 1967, of an aluminum stripe after current passage showing both void and hillock formation.

Another contribution came from Blech's moving island experiments where the relationship between stress gradients and the electromigration driving force was discovered. This is the basis for much of the work related in the following sessions of the symposium:

$$[(\partial\sigma)/(\partial x)] = [(Z^{*}e\rho j)/\Omega].$$

This work encompasses the concept of the "Blech length" and the critical current density length product which is important in understanding the fine line regime.

The third guest, P.B. Ghate of Texas Instruments (TI), spoke of the legacy owed to Huntington. Huntington's concept of the "electron wind" introduced in the late 1950s and early 1960s paved the way for understanding the physics of electromigration failure. Ghate spoke about the efforts at TI where electromigration was not only an interesting piece of science, but was an engineering problem that needed to be solved. For instance, not only did scientists need to know how long the average stripe lasted, but they needed to know the spread in the lifetimes and the distribution of the lifetimes in order to make design rules and to make predictions of reliability. The development of further understanding was stressed as the challenge of the future. For example, the problems of pulsed and AC electromigration were discussed. Ghate expressed his opinion that electromigration was an irreversible process and that AC stressing will also have an electromigration lifetime since any "recovery" due to current reversal is only partial. In addition, he told of the engineering solution at TI of providing a redundant conductor of TiW under the Al films to increase electromigration lifetime.

Rolf Hummel then entertained the audience with his charming account of the work performed at the University of Florida, including some war stories about funding, especially how quickly money was made available, although the sums were paltry by today's standards. He then related the great "which way does gold go?" controversy of the early 1970s. This was an exciting issue at that time. Hummel's gold seemed to go the opposite way from anybody else's. A session of a conference at IBM was held to resolve the issue, generating ample heated discussion. The paradox was later resolved as being due to the use of soda-lime glass microscope slides. The presence of the sodium leached into the gold film produced grain boundary grooving at the anode area where the fast diffusing sodium was concentrated by the electron wind. This produced the false impression of a reversal. Hummel concluded with a description of the "self-ionized physical vapor deposition" and its remarkable resistance to electromigration damage.

Paul S. Ho, formerly from IBM and now of the University of Texas—Austin, began his talk with more Huntington stories, where it was learned that Huntington had coined the word "electromigration." Ho then related some events during the early days at Yorktown Heights and East Fishkill. Solute effects were studied in conjunction with K. Howard of East Fishkill and his clever cross stripe experiment. It was seen that Cu would enhance diffusion in the lattice, but curiously slow down electromigration damage. It was concluded that Cu reduces grain boundary diffusion of Al, even though Cu itself diffuses rapidly through the grain boundary. Al intermetallic layer sandwich structures were also discussed as well as problems associated with multilevel metals.

R. Rosenberg, the last of the "grand masters" to speak, compared electromigration to allergists: Since nobody ever gets well, there will always be a job for those studying it. Rosenberg talked mostly about work performed before 1972 and acknowledged the many other contributors to electromigration science than the six being honored at the symposium. The effect of Cu additions, triple points as damage sites, grain boundary grooving, grain size divergences, barrier layers, and surface coatings were all studied by 1972. Rosenberg finished with some discussion of vacancy-solute interactions in grain boundaries and interfaces and the importance of geometry and solute depictions in W via failures.

The source of virtually all of the work presently being done can be seen in the early work of these six engineers and scientists. Perhaps current studies are more rigorous, perhaps they are more detailed, and perhaps they are concerned with regimes of performance and geometry unavailable when these six "grand masters" were working in the field, but the concepts developed 30 years ago are as valid today. This can be summed up in what was one of Rosenberg's closing statements, "There was a lot of good seeding work that went on...but problems still remain."

https://doi.org/10.1557/S0883769400035958 Published online by Cambridge University Press

of K. Golant and co-workers (General Physics Institute of the Russian Academy of Sciences) who utilizes a unique plasma-mechanical deposition process for fiber fabrication. In the chemical sensing arena, porous sol-gel silicate glasses are used to perform a variety of gas monitoring applications by R. Lieberman and co-workers (Physical Optics). T. Erdogan (Institute of Optics) presented the latest developments on Bragg fiber gratings and related issues. A related discussion was given by E. Delevaque (France Telecom CNET) on germanium-free, aluminosilicate fiber photosensitivity. A talk on employment of Bragg gratings in the structural sensing field was given by R. Measures (Univ. of Toronto), demonstrating the broad appeal of these devices. The symposium closed with a series of talks on novel glass compositions, such as the fluoroindate-erbium-doped glasses utilized by C.B. de Araujo and co-workers (Univ. Federal de Pernambuco in Brazil) for continuous wave upconversion sources.

Materials Scientists, Geochemists Study Reactions at Oxide/Water Interface

(See MRS Proceedings Volume 432)

Symposium S, Aqueous Chemistry and Geochemistry of Oxides, Oxyhydroxides, and Related Materials, brought together a diverse group of materials scientists and geochemists with a mutual interest in understanding reactions that occur at the oxide/water interface. Major topical areas included the structure and stability of oxide surfaces, colloid chemistry, and reactions including adsorption, surface complexation, precipitation, dissolution, and corrosion, with scientific interests ranging from basic science to applications.

V.E. Henrich (Yale) described how fundamental surface science studies on single crystal oxide surfaces can be used to probe surface chemistry. Such studies provide information regarding the adsorption, acid-base, and dissociation reactions that occur on specific surface sites including coordinatively unsaturated surface atoms, geometric defects such as kinks and edges, and valence-state defects, such as Ti^{3+} sites in TiO_2 surfaces. For example, recent results indicate that SO_2 interacts with Ti^{3+} to a much greater extent than T^{4+} surface sites, with an impact on the development of solid-acid catalysts.

G.E. Brown and his group from Stanford presented several talks showing how synchrotron-based x-ray absorption fine structure (XAFS) can be used to provide *in situ* information regarding adsorption and complexation on oxide surface from aqueous solutions. Analysis of XAFS results provide information regarding the oxidation state and coordination number of adsorbed ions, the nature of surface binding sites, and whether inner- or outer-sphere complexes are formed. Results have been used to predict how toxic species such as Cr and U migrate through soils and groundwaters.

Results were provided showing how oxide surface chemistry can be used in industrial applications. For example, M.A. Anderson's group at the University of Wisconsin is developing active elements for batteries, ultracapacitors, and fuel cells based on microporous oxides and oxyhydroxides. Development of electroactive oxides in a stable, high-surface-area form has led to the development of commercially viable products.

Symposium Support: Battelle, SNL.

Prospects Promising for Ferroelectric Thin Films

(See MRS Proceedings Volume 433)

A plenary session was held as part of Symposium T, Ferroelectric Thin Films V, on Advances and Prospects in Ferroelectric Technologies, which focused upon materials and systems of practical interest in device technologies. L.E. Cross (The Pennsylvania State Univ.) discussed relaxor ferroelectrics, which are interesting self-assembling self-limiting nanocomposite materials. New interest in this area is to combine relaxor and phase-switching

MRS Members Bid Merry Geil, Meeting Manager, Farewell

Merry Geil, planner and consultant of the Materials Research Society's Spring and Fall Meetings for over 10 years, retired on June 14, 1996. An impromptu farewell celebration for Geil took place at the Wrap-Up Meeting of the 1996 Spring Meeting in San Francisco. Hosted by two of the 1997 Spring Meeting Chairs, David Eaglesham and Alexander King, the event included presentation of a commemorative plaque to Geil for her many years of service. Dozens of former and current officers, councillors, and meeting chairs, and other MRS staff and volunteers attended the ceremony to extend their best wishes.

During a wrap-up session for the MRS 1996 Spring Meeting, MRS volunteers honor Merry Geil for her many years of service as Meeting Manager. She retired June 14. Left to Right (standing): G. Slade Cargill III (former MRS president), A. Kay Hays (MRS Treasurer), Merry Geil, Robert Hull (MRS First Vice President), Alex King (MRS 1997 Spring Meeting Chair); (seated): David Eaglesham (MRS 1997 Spring Meeting Chair).

During her career at MRS, Geil has implemented several improvements to MRS meetings. Specifically Geil has handled the growth of the MRS Fall Meeting as attendance grew from one hotel into three interconnected facilities. She has also coordinated the transfer of symposia-abstract receipt from symposium organizers to MRS headquarters, easing the administrative burden on the organizers. Most recently, with the introduction of the MRS homepage on the World Wide Web, she has worked extensively to design, test, and implement a software program facilitating electronic receipt of abstracts.

Geil's efforts for MRS meetings have always been undertaken with a personal touch. "Merry's greatest strength is her nurturing capacity. She has developed a special relationship with all of the meeting chairs, officers, and councillors with whom she has come in contact. We certainly hate to see her go," said MRS president Carl Thompson.

Former MRS president Gordon Pike also commented on Geil's contributions to the meetings and to the society as a whole. "As someone with a long history of organizing symposia and meetings at MRS and in other organizations, I have seen a tremendous improvement in headquarters support during Merry's tenure. I have frequently been told by fellow researchers how delightful it is to run a symposium at MRS. The organization and processes shepherded by Merry have really been useful and are a benchmark for the community."

The Society has hired Dick Stevens, formerly of Westinghouse communications and meetings, to assume the post of meeting manager. "We anticipate a seamless transition of duties to the new manager and continued positive interaction with our meeting volunteers. Dick's enthusiasm and commitment will build upon the tradition of quality member service and meetings operations maintained by Merry during her tenure," said Gail Oare, Director of Meeting Activities.

Geil expressed deep satisfaction in regard to her experience at MRS over the years, "The opportunity to work with the incredibly talented and thoughtful scientists of MRS is one which I value most highly. Serving with each group of meeting chairs and symposium organizers as a member of the leadership team for each of these diverse and technically strong meetings over the past 12 years has been challenging, intriguing, and most satisfying. Thank you very much for shaping so many fond memories."

behavior in the high zirconia PZT compositions, to control switching electric field, its temperature dependence, and hysteresis. J. Alexander sketched the DARPA interests in thin- and thick-film systems with emphasis upon integration with silicon semiconductors and semiconductor packaging. M. Sayer discussed thin- and thick-film coating work at Queen's University for a broad range of ferroelectric and piezoelectric applications. L. Kabacoff (ONR) gave a good rendition of the major Navy interests in transducers and transducer materials, with the focus moving toward higher frequency systems for shallow water imaging and electromedical applications. R. White (UC—Berkeley) discussed the applicability of piezoelectric thin-film materials to microelectromechanical systems (MEMS). He described a wide range of resonator, motor, and microchemical applications mostly using zinc oxide films but with the suggestion that performance in several instances would be improved using PZT. The final paper, given by D.M. Smyth (Lehigh Univ.), described experiments to explore transport processes in the bismuth oxide layer structure materials now of interest in film form for Fe RAM. The talk emphasized similarities and differences from earlier studies on transport in $BaTiO_3$ and PZTs. The whole session was very well-attended and enthusiastically received with people even clustered around the monitor outside the room.

Symposium Support: SNL, Motorola, Samsung Adv. Institute of Technology.

Structure of Layered Systems Connects to Mechanical Behavior
(See MRS Proceedings Volume 434)

Layered materials and systems based on metallic, intermetallic, polymeric, and ceramic constituents are becoming increasingly important to meet the structural requirements of current and future high performance products. In response to various research and development activities in these areas, Symposium U was organized to cover a range of topics dealing with Layered Materials for Structural Applications. The meeting began with overviews on structural applications of such systems and highlighted applications such as thermal barrier coatings, aircraft structural components, and wear-resistant coating for a variety of applications. Processing techniques such as electron-beam deposition processing, reactive sputter deposition, sedimentation processing, pressureless co-sintering, and rapid prototyping via laminated object manufacturing were subsequently covered in a following session. Microstructural stability issues were additionally covered and highlighted as a critical area requiring further investigation. The largest number of papers presented focused on the mechanical behavior and modeling of layered systems and revealed significant effects of layer thickness, spacing, and constitutent properties on the fracture and fatigue behavior of such systems. While considerable work has investigated the issues of strength and toughness, less has currently focused on the behavior of such systems under either cyclic loading conditions or the high temperature behavior.

Symposium Support: ONR.

Organic/Inorganic Hybrids are Fertile Ground for Examining Structure-Property Relationships
(See MRS Proceedings Volume 435)

Symposium V, Better Ceramics Through Chemistry VII—Organic/Inorganic Hybrid Materials, focused on synthesis, structure, and properties of organic-inorganic hybrid materials. Porosity in hybrid materials was a recurring theme. K. Shea (UC—Irvine) noted that the original idea behind synthesis of organic-bridged silicates was to create open structures with pores whose dimensions were controlled by chemistry. Shea's disappointment concerning lack of controlled porosity was explained by D. Shaefer (SNL) who showed that porosity in these hybrids was due to polymer-solvent phase separation and was, therefore, only indirectly related to the bridge chemistry. Several groups have achieved molecular scale porosity by plasma or thermal pyrolysis of organic moieties. Y.F. Lu (Univ. of New Mexico), for example, achieved narrow pore-size distributions by copolymerizing organically modified silicates with fully inorganic monomers.

Strategies for achieving ceramic-like hardness without loss of polymer-like processability ranged from molecular level engineering of rigid silica "cubes" to new schemes to incorporate nanosized particles into polymers. G. Wilkes (VPI & SU) showed that appropriately functionalized organics could be copolymerized with silicates to yield adherent coatings with impressive scratch resistance. Hybrids can also have an impact on toughness to brittle materials. J.D. Makenzie (UCLA) for example, was able to prepare low-density aerogels with a rubbery character by incorporating up to 20% siloxane chains into porous silicate aerogels. Ideas for increasing toughness for cements and dental materials were also presented.

Numerous studies were reported that sought to couple the processability of polymers with tailored electrical and optical properties. Strategies ranged from incorporation of chloroplasts for photosynthesis to molecular design of electro-optic moieties.

Hybrids are rife with opportunity for materials scientists. The field of hybrids is principally dominated by molecular level chemistry. Chemists are producing new materials at an increasing pace but many of these materials go uncharacterized apart from basic chemical analysis. Mechanical properties often remain undefined. Significant issues regarding phase separation and related materials issues are yet to be clarified and further work is needed on this issue.

Symposium Support: Eastman Kodak, Dow Corning.

Computational Methods Bridge Size and Time-Length Scales

Symposium W on Computational Materials Science—Structural, Mechanical, and Transport Properties was directed at the materials science issues needed to bridge size and time-length scales. Researchers from the traditional subdisciplines of materials science—polymers, ceramics, and metals—exchanged ideas relating to optimal modeling strategies and methodologies as they pertain to bridging the approaches used for the atomistic, microscopic, and macroscopic levels.

The symposium featured a hierarchical, methodology-based framework:

- *Electronic structure and atomic forces:* Quantum methods overview; basic force field development; direct application of quantum methods to bulk systems with applications to ceramics, defects, and organic materials.
- *Atomistic modeling: methods and applications:* First principle thermodynamics and alloy theory and atomistic simulation of polymeric and organic materials.
- *Microstructural evolution and interfaces:* Theoretical approaches to morphology prediction, dynamics of structure formation, property prediction and applications.
- *Mechanical and thermal properties:* Finite element analysis; grain size and structure prediction; evolution of structure; residual stress and strain; aggregate models; applications.

Bond order potentials and their applications were of major interest. D. Pettifor (Univ. of Oxford, UK) in the meeting's opening session introduced the length-scale problem for electronic structure methods on electronic and atomistic size scales. Subsequent discussion focused on their derivations, the comparative strengths of the multipole and density matrix approaches, and comparisons with conventional atomistic interaction potentials. Extension of the electronic level knowledge typically focused on magnetic and conductive properties of films and material synthetic methods. The implications of these approximations were later examined in presentations on the phase diagram and physical properties of organic and polymeric materials. The microstructural session focused its efforts on comparing the nature and spatial extent of microstructural interaction potentials as they affect consolidation and grain growth within a material. It was frequently observed that modeling the behavior of advanced materials requires the use of hybrid computational techniques in order to span a vast range of length and time scales.

Acceptance of Degradable Polymers Slow Despite Technical Progress

Symposium Z on Environmentally Degradable Polymers was held over three days with the major divisions: introduction to degradation and testing, natural polymers and renewable resources, water-soluble degradable polymers, and natural/synthetic polymer blends. Plenary lectures were given by S. Huang (Univ. of Connecticut), who summarized the state of the field; R. Narayan (Michigan Biotechnology Institute), who gave an overview of terminology and testing protocols; D. Kaplan (ARL at Natick, MA), who reviewed biodegradable polymers from renewable resources; and J.S. Willett (USDA, Peoria, IL), who reviewed starch-based biodegradable polymers.

An impromptu discussion took place on environmentally degradable polymers, moderated by G. Swift (Rohm and Haas Co.). The discussion ranged from technical issues to the exploration of the lack of current widespread acceptance of environmentally degradable polymers. The general consensus appeared to be one of a gradual acceptance beginning in suitable markets where cost/performance is not an issue, for example, fast food packaging and farm land applications for temporary cover of crops, and, perhaps, water-soluble polymers. Technical approaches

Tenney Gives Plenary Talk on Challenges of Aerospace Materials Research

On Monday night, Darrel R. Tenney, Chief of the Materials Division of the NASA Langley Research Center, opened his plenary address with a photo of Jerusalem, "Even in the midst of a revolution in information technology, there will always be a need for aircraft to transport us to the unusual parts of the world, where we have a chance to experience the scenery."

In his talk, "Aerospace Materials Research: Changing Times, Trends, and Challenges," Tenney illustrated several changes in the focus and progress of materials research in the field of aerospace due to world events, including the oil embargo of the 1970s and the U.S. deregulation of airlines in the 1980s. After the Aloha Flight accident in 1988 in which Flight 243 lost a major section of the fuselage, materials researchers directed their study on a better understanding of damage tolerant issues and on better inspection techniques for small cracks around rivets. Much of their success in improving conditions stemmed back to fundamental research done in the 1970s and 1980s related to computational methods, 3-D configurations, and elastic/plastic methodology.

The aerospace industry is currently challenged with environmental regulations, including the reduction of noise pollution. In the light of environmental and economical issues, researchers are striving for aircraft that would fly Mach 2.0–2.4, have a range of about 5,000–6,000 nautical miles, carry about 300 passengers, have a gross take-off weight of about 700,000 pounds, and be affordable for the average passenger. Such an aircraft would need to have an airframe design lifetime of about 70,000 hours, 60,000 hours at temperatures as high as 177°C at Mach 2.4 or 110°C at Mach 2.0. The materials distribution currently being considered include titanium and aluminum alloys, high-temperature composites, adhesives and fuel tank sealants. Long-life lightweight materials are an enabling for the successful development of a commercially viable supersonic transport aircraft.

were expected to continue in the current direction toward either natural resource modification, starch, cellulosics, or synthetics with structural units similar to polymers found in nature, polyesters, and polyamides, for example. In the long term, the potential for plant production of polyhydroxyalkanoates (polyesters such as polyhydrocybutyrate) through genetic modification is possible but no meaningful data is available on cost which will include the more predictable polymer isolation costs and, also, the unpredictable balance of land use for polymers versus food crops.

Symposium Support: Rohm and Haas Co., Procter & Gamble.

Researchers Produce Innovative Instrumentation

Symposium AA introduced Innovations in Instrumentation for Materials Research, a new venture for MRS. The premise for the symposium was that there has not been an outlet in the field for instrumentation innovations which are produced by researchers in the course of their materials research. Seven sessions were organized from the 90 submitted abstracts: Surface Analysis, Microanalysis Techniques, Scanned Probe Microscopies, Mechanical Properties, Detector Technologies, Electron Microscopy, and Diffraction.

Symposium Support: E.A. Fischione Instruments Inc., Denton Vacuum Inc., RJ Lee Grp, JEOL, Philips Electronic Instruments, LEO Electron Microscopy.

Natural and Synthetic Materials Compared in Musical Instruments

The Acoustical Society of America joined the Materials Research Society in sponsoring Symposium BB on Materials in Musical Instruments. Presenters took advantage of the opportunity for musical illustrations, particularly in the string and percussion portions of the sessions. While D. Hosler (MIT) generated much interest with her archaeological paper concerning metallurgy of ancient Mexican bells (see Historical Note, this issue), string and percussion instruments captured the attention of participants. Materials interest was particularly emphasized through synthetic materials used by K.A. Decker (Rainsong Graphite Guitar) in guitars and by L.F. Bazinet (Akzo Nobel Fortafil Fibers) in banjos. G. Eban's (Cos Cob, CT) discussion of traditional guitar woods lent a balance between natural and synthetic materials. Panelists in the evening demonstration contrasted synthetic and traditional instruments, as well as introduced symposium participants to the unique timbre of Caribbean steel pan sounds. Materials in percussion instruments were highlighted by U.J. Hansen's (Indiana State Univ.) presentation about progress in steel pans. The entire symposium was capped by a performance on a set of double second pans by T. Miller, a prominent pan performer and arranger in the Bay Area in California.

Adhesion, Nanoindentation Probed
(See MRS Proceedings Volume 436)

Symposium CC, Thin Films: Stresses and Mechanical Properties, was kicked off with a packed-audience, evening tutorial on the mechanical properties of thin films by S. Baker (Max Planck). T. Michalske and J. Houston (SNL) opened the regular sessions discussing the interfacial force microscope probing of metallic surfaces with alkane thiolate monolayer coverages. Adhesion can be sensed using such approaches as well. In this session, those discussing multilayers included T. Trimble and B. Cammarata (Johns Hopkins) and P. Mikarimi (SNL). Somewhat more robust de-adhesion strategies for measuring hard protective films were discussed in the fracture and de-adhesion sessions by groups from Poitiers, France; Sandia; Stanford; and Mainz, Germany but more compliant systems and the means of mechanically measuring thin film strength were evaluated by scientists T. Marieb and H. Fujimoto (INTEL), interested in multilayered polymer systems.

Nanoindentation was featured in an all-day, two-session format devoted to mechanical property methods and highlighted by invited talks from J. Pethica (Oxford) and W. Knauss (Cal Tech) using scanning tunneling microscopy in various ways to understand small volume deformation. Of particular interest was a joint study at the Naval Research Laboratory and the University of Minnesota, as presented by S. Corcoran, which gave a staircase load displacement profile in [111] oriented gold single crystals, somewhat at variance with the smoother curves found with a monomolecular buffered gold surface in the interfacial force microscope by Sandia researchers. Resolution of such differences should lead to in-depth understanding of nonlinear effects at metal surfaces undergoing nm level displacements. This was followed by an afternoon session with B. Nix's illuminating discussion on the plane strain bulge test which solves some edge problem effects normally encountered in thin pressurization near clamped surfaces.

Additional highlights included challenging talks by T. Page (Newcastle) and J-L. Loubet (Ecole Centrale de Lyon) using various nanomechanical probes in either the monotomic or the AC mode to probe tribological coatings or the viscoelastic nature of polymer surfaces. With diamondlike carbon and polymer thin film systems coming on line as abrasion resistant coatings, documentation of their mechanical response is becoming of increasing industrial importance. Several sessions were then devoted to stress and strain relief effects in thin films, interconnects, and epitaxially grown systems. The highlight of the joint session with Symposium L was an illumination of curvature effects and strain relief in graded thin films, by B. Freund (Brown Univ.).

Synchrotron Techniques Detailed
(See MRS Proceedings Volume 437)

Symposium DD on Applications of Synchrotron Radiation Techniques to Materials Science provided a wide range of both oral presentations and posters showing data on a wide array of topics concerning the use of synchrotron radiation in materials science. Experimental techniques that were covered included extended x-ray absorption fine structure (EXAFS), synchrotron x-ray diffraction and fluorescence microprobe, and soft x-ray photoemission, while the types of materials systems studied ranged from alloys to polymers to single crystals of metals. In one example, anomalous x-ray scattering research was reported that was focused on rare earth metaphosphate glasses, while another case addressed the study of diamond films on core-level photoabsorption. Photoemission studies were also detailed relating to the investigation into the chemistry and physics of carbon nitride films.

Symposium Support: Physical Electronics, Blake Industries. MRS