MRS Council Establishes Two Committees: Information Services and Materials MicroWorld

The Council of the Materials Research Society has recently created two committees: Information Services and Materials MicroWorld. In order to add these committees to the Society, Council had to make changes to the MRS Bylaws.

According to Article IX—Bylaws, "Members of the Society shall be notified of Bylaw amendments. Any one hundred (100) Members of the Society may petition the Council for a referendum on any such amendment or other action of the Council; any such referendum shall be submitted to the Members of the Society by mail ballot and must be approved by two-thirds of those voting on it." For more information, contact Kathy D'Biagio, Administrative Assistant, Governance; Materials Research Society, 506 Keystone Drive, Warrendale, PA 15086-7573, USA; tel. 724-779-3004 ext. 523; fax 724-779-8313; or e-mail dbiagio@mrs.org.

Council has approved the following two amendments to the MRS Bylaws.

MRS

<u>1) Creation of an Information Services Committee, Council Motion C:2000:47, December 1–2, 2000.</u>

E. Information Services Committee

The Information Services Committee shall be chaired by a Presidential appointee responsible to an Executive Committee liaison designated each year by the Executive Committee; the Executive Committee liaison will be an ex officio member of the Committee.

The Information Services Committee will review and oversee materials information services undertaken by the Society, including traditional print publications and materials information delivered in electronic forms. The responsibilities of the committee shall be: a) Insure that traditional print and electronic publications are timely, of high technical and editorial quality, and refereed according to the policy of each publication; b) Recommend to the Executive Committee or Council appropriate policies to direct the editorial and business practices of each publication or electronic information service; c) Identify, plan, and initiate new electronic services related to established publications within the constraints established by Council; d) Engage in long-range and strategic planning for existing and future publications and electronic services; e) Develop standard practices and models as guidance for those contemplating publications and electronic services under the aegis of the Society; f) Assist Headquarters in identifying technology, process, and resource issues involved in planning, developing, and maintaining publications and electronic information services; g) Serve as liaison on behalf of MRS to external organizations also engaged in materials research related information services.

<u>2) Creation of a Materials MicroWorld Committee, Council Motion C:2001:10, April 20, 2001.</u>

G. Materials MicroWorld Committee

The Materials MicroWorld Committee shall be chaired by a presidential appointee responsible to a Council member designated each year by the Executive Committee; the liaison Council member will be an ex officio member of the Committee. The Committee shall assure that the project moves forward to meet its goals according to the established timeline and with a level of excellence reflective of the traditions of the Society. To this end, the Committee shall oversee all aspects of the design, development, construction, and circulation of the Materials MicroWorld traveling exhibit modules and the associated support material on the Society's website. The oversight responsibilities specifically include the development and execution of budgets for the project, fulfillment of the provisions of the grant from the National Science Foundation, the development and execution of contractual arrangements with a contractor to execute the project, the planning and execution of plans to obtain funds from industrial and foundation supporters, and liaison with appropriate advisory and interest groups. The chair and members of the Committee, to be appointed each year by the President, shall include all Principal and Co-Principal Investigators of the NSF grant, at least one representative each from the Public Outreach Subcommittee and the Academic Affairs Committee, and the MRS Treasurer as an ex officio member.

MRS Workshop Series Presents Topics on Device Technology, COS, and MEMS

The Materials Research Society Workshop Series offers three topics in September. The **International Workshop on Device Technology**, chaired by Israel Baumvol of the Instituto de Física–UFRGS, will be held September 3–5 in Porto Alegre, Brazil. **Dielectric Science and New Functionality in Device Physics for Crystalline Oxides on Semiconductors** (COS) will be held September 11–12 in Chattanooga, Tennessee. The organizers are Rodney McKee (Oak Ridge National Laboratory), Kurt Eisenbeiser (Motorola), Darrell Schlom (The Pennsylvania State University), and Charles Ahn (Yale University). **MEMS: Materials Issues Workshop**, chaired by Ainissa G. Ramirez (Bell Labs, Lucent Technologies) and Richard P. Vinci (Lehigh University), will be held September 19–21 in Miami, Florida. Look for updates on the MRS Web site: www.mrs.org/meetings/.

Device Technology

This workshop will address alternatives to SiO_2 as gate dielectrics for future Si-based microelectronics. Presentations will focus on different aspects of electrical, structural, and physicochemical characterization of alternative oxide materials in ultralarge-scale-integration devices. Developments in sub-2-nm oxide and oxynitride gate dielectrics and the emerging field of oxide and oxynitride films on SiC will also be explored.

Topics will include

- electrical characterization of metal-oxide-semiconductor structures using novel high-κ oxides on Si;
- deposition and growth methods of high-κ gate dielectrics on Si;
- atomic-scale understanding of thin and ultrathin films of high-κ oxides and their interfaces with Si;
- electrical characterization and atomic-scale understanding of stability and post-deposition annealing of high-κ materials on Si;
- growth, deposition, and atomic-scale characterization of subnanometric silicon nitride, oxide, and oxynitride films as intermediate layers between high-κ oxides and Si substrates;
- the state of the art on growth and electrical and physicochemical characterization of sub-2-nm silicon oxide and oxynitride films of Si; and
- electrical characterization and atomic-scale understanding of oxide and oxynitride films on SiC.

For more information, contact Israel Baumvol, Instituto de Física, Universidade Federal do Rio Grande do Sul, Av. Bento Goncalves, 9500, 91509-900 Porto Alegre RS, Brazil; e-mail high-k@if.ufrgs.br.

Crystalline Oxides on Semiconductors (COS)

Crystalline oxides grown commensurately to a semiconductor are emerging as a new physical system for metal-oxide-semiconductor (MOS)-based device physics. This workshop will focus on opportunities and functionality in semiconductor-device physics using crystalline oxides on semiconductors (COS).

COS in a MOS capacitor is a physical system based on dielectric epitaxy in a monolithic thin film with a semiconductor. Examples of the diverse characteristics of crystalline oxides include ferroelectricity, piezoelectricity, and ferromagnetism. A primary example for new functionality comes by the coupling of the anisotropy of Curie phenomena in an oxide to the charge state in the underlying semiconductor. Issues of dielectric science and electron and hole scattering at a crystalline oxide interface with a semiconductor underpin the device-physics opportunities. The purpose of the workshop is to bring together scientists and engineers who are interested in both the fundamental science opportunities and device functionality in this new physical system.

Georg Bednorz of IBM—Zurich is scheduled to give the plenary address on "Crystalline Oxides on Semiconductors—Enabling the Introduction of New Functionality in Semiconductor Devices." Invited speakers include Fred Walker, Oak Ridge National Laboratory; Scott Chambers, Pacific Northwest National Laboratory; Curt Billman, The Pennsylvania State University; Karin Rabe, Rutgers University; T.P. Ma, Yale University; Malcolm Stocks, Oak Ridge National Laboratory; Raymond Tung, Agere Systems; Jerry Woodall, Yale University; Jasprit Singh, University of Michigan; Antoine Kahn, Princeton University; Raynien Kwo, Bell Labs, Lucent Technologies; Bruce Kane, University of Maryland; Jeremy Levy, University of Pittsburgh; and Bill Ooms, Motorola.

Topics include

- molecular-beam epitaxy concepts and methodologies relative to COS;
- interface electrical structure;
- piezoelectric phenomena and ferroelectric lithography;
- interface electrical structure theory;
- COS structures and semiconductors on insulator architectures;
- novel materials and COS; and
- quantum computing physics on semiconductors.

For more information, contact Member Services, Materials Research Society, 506 Keystone Drive, Warrendale, PA 15086-7573, USA; tel. 724-779-3003, fax 724-779-8313, and e-mail info@mrs.org.

MEMS

This workshop will focus on materials issues and opportunities in microelectromechanical systems (MEMS). The MEMS community is heavily driven by the push for products, yet these thrusts may overlook underlying concern with materials properties, behavior, and reliability. Topics will include

- *characterization*: nanoindentation, interferometry, and other techniques, MEMS-based testing, and modeling;
- *processing*: release procedures, processing physics, and protocols;
- *materials*: metallization, wear-resistant coatings, tunable materials, bio-MEMS materials, materials behavior, and new MEMS materials; and
- *reliability*: failure mechanisms, design, and testing for reliability.

For more information, contact Member Services, Materials Research Society, 506 Keystone Drive, Warrendale, PA 15086-7573, USA; tel. 724-779-3003, fax 724-779-8313, and e-mail info@mrs.org. MRS

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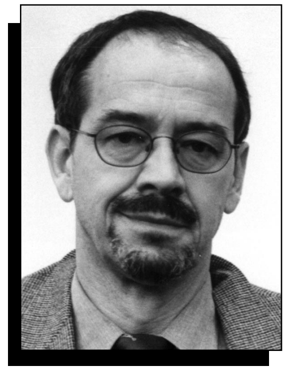
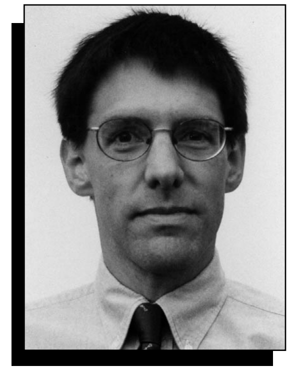
Bao, Fitzgerald, Gösele, and Rodbell to Chair 2002 MRS Spring Meeting

Zhenan Bao

Eugene A. Fitzgerald



Ulrich M. Gösele



Kenneth P. Rodbell

The 2002 Materials Research Society Spring Meeting in San Francisco, April 1–5, will be chaired by Zhenan Bao (Bell Labs, Lucent Technologies), Eugene A. Fitzgerald (Massachusetts Institute of Technology), Ulrich M. Gösele (Max Planck Institute of Microstructure Physics—Halle), and Kenneth P. Rodbell (IBM T.J. Watson Research Center). The meeting's 24 symposia are gathered into four clusters: Electronic and Optoelectronic Materials, Molecular and Biomaterials, Nano/Microstructured Materials, and a General category.

Zhenan Bao is a Distinguished Member of Technical Staff at Bell Laboratories, Lucent Technologies. She attended Nanjing University (1987–1990) in China and the University of Illinois—Chicago (1990–1991), where she completed her undergraduate studies. She received her PhD degree in chemistry from the University of Chicago in 1995 and then joined Bell Laboratories. Her current research interests include rational design and synthesis of organic and polymeric semiconductors for thin-film field-effect transistors, light-emitting diodes, organic lasers, plastic superconductors, nonlithographical patterning of optoelectronic devices, and self-assembled molecular structures and micro-objects. Bao is a Guest Editor of an upcoming issue of *MRS Bulletin* on electroactive polymers, scheduled for June 2002.

Eugene A. Fitzgerald is a professor of materials science and engineering (MSE) at the Massachusetts Institute of Technology (MIT). He received BS and PhD degrees in MSE from MIT (1985) and Cornell University (1989), respectively. From 1989 to 1994, Fitzgerald performed research at AT&T Bell Laboratories in the area of lattice-mismatched semiconductors and devices. In 1994, he accepted a position at MIT. His group's research activities include electronic materials, novel semiconductor heterostructures and devices, and heteroepitaxial integration. He currently has more than 20 awarded or pending patents, and has been the author or co-author of over 100 technical papers. He is Chair and Founder of Amberwave Systems Corporation.

Ulrich M. Gösele has been a director at the Max Planck Institute for Microstructure Physics in Halle, Germany, since 1993. For many years, he was a J.B. Duke Professor of Materials Science at Duke University in North Carolina. Prior to that, he worked at the Siemens Research Laboratories in Munich. He has held visiting appointments at the IBM T.J. Watson Research Center, the NTT LSI Laboratories in Atsugi, Japan, and the Atomic Energy Board in South Africa. His research interests include defects and diffusion processes in semiconductors, reaction kinetics in thin films, quantum effects in porous silicon, ferroelectric thin films, semiconductor wafer bonding, and photonic crystals. Gösele is a Fellow of the American Physical Society and the Institute of Physics.

Kenneth P. Rodbell is a Research Staff Member at the IBM T.J. Watson Research Center. He joined IBM Research in 1989 after spending three years at the IBM Semiconductor Development Laboratory in East Fishkill, N.Y. Rodbell received his PhD degree in MSE from Rensselaer Polytechnic Institute (RPI) in 1986. He previously earned his MS (1983) and BS (1982) engineering degrees from RPI. Rodbell's research interests are in Si-based electronic materials, specifically thin-film metallurgy and crystallographic texture, intermetallic formation, electromigration, chemical-mechanical polishing, $1/f$ noise in metallic films, positron annihilation spectroscopy, radiation-induced soft errors, and low-κ dielectrics. Rodbell has 90 refereed publications and 12 U.S. patents (with 26 pending). He was a symposium co-organizer for MRS in 1993, 1994, and 1999. MRS

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2001 MRS Spring Meeting Adds Element of Fast, Large, and Cost-Effective Trends in Materials Research

Research trends—from the drive for ever-smaller and better-performing devices to the development of materials larger in scale, cheaper to produce, and easier to fabricate—were on display at the 2001 Materials Research Society Spring Meeting. Held at the San Francisco Marriott and Argent Hotels on April 16–20, the Meeting covered topics such as large-area electronics, femtosecond science, and light-emitting diodes. Chaired by Nicholas Cowern of Philips Research Laboratories, Tomás Díaz de la Rubia of Lawrence Livermore National Laboratory, Chad A. Mirkin of Northwestern University, and Cynthia Volkert of Max-Planck-Institute—Stuttgart, the Meeting also featured presentations on molecular electronics, practical aspects of microelectronics, structure–property fundamentals, nano- and biomaterials, and various characterization techniques (see Technical Sessions). A late news session was held on the recently discovered MgB_2 superconductor (see Sidebar).

The 32 technical symposia were categorized into clusters, with 1579 oral presentations and 751 posters. Special events included the plenary session, which featured a talk on electroluminescent polymers by Nobel Laureate Alan J. Heeger of the University of California—Santa Barbara. Kristi S. Anseth of the University of Colorado was honored with the MRS Outstanding Young Investigator Award. Gold and Silver Graduate Student Awards and poster awards were also celebrated. Symposium X presented overviews on the "Frontiers of Materials Research" for technical nonspecialists. See Sidebars covering these and other events. The equipment exhibit featured more than 125 exhibitors from around the world, displaying a range of equipment, services, products, publications, and software.

Technical Sessions

Scientists described the strides they made toward simple, high-throughput methods in materials research. In Symposium Z, which addressed ways to process organic optical devices, S.R. Forrest (Princeton) described the process of cold welding followed by liftoff in the fabrication of metal cathodes for OLEDs and transistors. The process takes only 3–4 min and can produce pattern definition <100 nm. In this process, a hard material is prepatterned to make a stamp. It is then coated with the metal of the cathode material. The coated metal is then stamped onto a layer of the cathode material, forming a good bond where the stamp is patterned and fracturing the stamped layer at the edges of the stamp. Lifting the stamp then lifts off the metal in the regions where it was cold-welded. One limitation of this process is materials selection. The proper adhesive and cold-weld properties are needed. Oxides, for example, can prevent welding. Forrest described how such a method could be used to make devices by the mile instead of by the inch. A continuous process could be envisioned such that a flexible substrate goes through a series of rollers to deposit the organic material by CVD, to deposit the cathode material, and to emboss the pattern.

Silicon device requirements are also moving toward large-area electronics and simple processing methods. S. Wagner (Princeton) reported, in Symposium Z, on electrophotographic printing of toner etch masks and silver metallization, and the fabrication of copper metallization from ink-jet printed precursor patterns. His goal is to produce smart electronic surfaces, electrotextiles, and other functional large-area electronics. Contrasting the multibillion-dollar price tag of semiconductor for fabrication facilities, some new electronic developments start with ink-jet printers and other standard printing technologies. Wagner compared the cost of printing a mail order catalogue (pennies/m^2) to producing silicon ICs ($50,000–$500,000/m^2), illustrating the tremendous cost savings when electronics are produced with traditional printing technology. The direct printing method also collapses many processing steps into one.

Ink-jet printing can be used for building soft devices as described by P. Calvert (Univ. of Arizona) in Symposium C. In the process of combining soft and hard materials into devices, Calvert used modified commercial ink-jet printers to print uniform layers and patterns of epoxy resin and amine curing agent onto silicon substrates. Nobel Laureate A.G. MacDiarmid (Univ. of Pennsylvania) reported on the progress in developing disposable electronic circuits such as those produced by a method that, in the end of the process, does not involve the printing of a conducting polymer, and they use only a conventional office laser printer and toner, unmodified in any way. With this process 10,000 pixel/in.^{2} polymer-dispersed LCDs have been produced. MacDiarmid introduced the selective deposition of conducting polymers as a function of the degree of hydrophobicity/hydrophilicity of the substrate surface on which the polymer was deposited. His method exploits the observation that a commercial dispersion of polythiophene derivation wets a plastic transparency, but not the lines printed on the transparency by the office laser printer. The printed lines can be easily removed in a few seconds by ultrasonic treatment, leaving a pattern of deposited material on the substrate whose shape was originally described by the now *nonexistent* printed lines.

In the field of large-area electronics, A.A. Darhuber (Princeton) has found that offset printing allows for fast and parallel pattern transfer onto large areas and high throughput at low costs. In Symposium D, Darhuber said that the guidelines developed for microscale offset printing of 5–100-μm thick patterned films on silicon and glass consist of the use of wetting surfaces to prevent contact line migration, high viscosity inks, and high-speed plate separation.

Electronic Materials

Lighting up the room in Symposium G with white LEDs, G.O. Mueller (LumiLeds Lighting, a joint venture of Agilent Technologies and Philips Lighting Advanced Laboratories) discussed the progress toward solid-state lighting. Two major developments in the last two years have enabled the expanded use of LED lighting: development of a full range of bright LEDs spanning the visible spectrum and the availability of suitable phosphors for generating white light. The phosphors (also called "color converters" because they convert, for example, blue into yellow or blue into red and green) have not been perfected but have opened additional application possibilities. LEDs offer tremendous energy savings compared to incandescent lighting. Switching to this lighting could save 400 terawatts/year, or ~$37 billion/year. In the short term, LED lighting is being used for traffic signals, car tail lights, and signage. Mueller discussed the AlGaInP/GaP truncated inverted pyramid for red light, which maximizes efficiency because almost all light is inter-

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nally reflected. He also described the flip chip for producing green and blue.

In the area of PLEDs, Y. Yang (UCLA) reported, in Symposium C, high-performance diodes using a low temperature and a plastic lamination process. Blue, green, and red-emitting PLEDs were fabricated by laminating different luminescent polymers and organic compounds together to form the active media. Yang said that this approach eliminates the issue of organic solvent compatibility with the organic layers for fabricating multilayer PLEDs. S. Cinà (Cambridge Display Technology) showed how polymer blends can be used to produce PLEDs with high efficiency, very high brightness, and long lifetime. These are the requirements if this technology is to be used for back-lighting and passive display applications. A highly efficient (9%) pure red color phosphorescent OLED with exceptional external quantum efficiency and brightness at low operational voltages was reported by G. Jabbour's group (Univ. of Arizona). This OLED is composed of a hybrid polymer with a simple three-layer architecture, and uses a very efficient electron injecting, air-stable cathode based on aluminum.

Coffee breaks between sessions provide an opportunity for Meeting attendees to discuss research.

In Symposium B on molecular electronics, M. Reed (Yale) described the design and measurement of molecular electronic switches and memories. He covered synthesis strategies using self-assembly incorporated into electronic structures. In R.S. Williams' (HP) presentation on the use of molecules as electronic switches, Williams said that molecules represent the key to future computing needs, which will start the "real" age of computing. In questioning the physical and architectural limits for molecular-scale devices in computers, R. Lytel (Sun Microsystems) said that for the next decade, electronics will continue to be scaled down, perhaps adding cooling systems, lowering the voltage for CMOS, merging logic and memory, and using SiGe bipolar transistors to keep to Moore's law. For molecular devices to join the race, Lytel said that such devices will need to be deterministic, with a precise map, not statistically based, so that errors (e.g., due to cosmic rays) can be detected and corrected, and design errors essentially nonexistent.

In a study with femtosecond laser pulses, E. Mazur (Harvard) discovered that when a flat (111) surface of silicon was irradiated in an environment with sulfur hexa-

ACRONYM KEY

2D: two-dimensional
3D: three-dimensional
AFM: atomic force microscopy
AFOSR: Air Force Office of Scientific Research
AFRL: Air Force Research Laboratory
ANL: Argonne National Laboratory
ARO: Army Research Office
BNL: Brookhaven National Laboratory
Caltech: California Institute of Technology
CIGSS: Cu(In,Ga)(Se,S)$_2$
CMOS: complementary metal-oxide semiconductor
CMR: colossal magnetoresistance
CVD: chemical vapor deposition
DARPA: Defense Advanced Research Projects Agency
DRAM: dynamic random-access memory
fcc: face-centered cubic
FET: field-effect transistor
GMR: giant magnetoresistance
HBT: heterojunction bipolar transistor
hcp: hexagonal close-packed
HEMT: high-electron-mobility transistor
HF: hydrofluoric acid
HP: Hewlett-Packard
HRTEM: high-resolution transmission electron microscopy
IC: integrated circuit
IR: infrared
LANL: Los Alamos National Laboratory
LBNL: Lawrence Berkeley National Laboratory
LCD: liquid-crystal display
LED: light-emitting diode
LLNL: Lawrence Livermore National Laboratory
MBE: molecular-beam epitaxy
MEMS: microelectromechanical system
MESFET: metal-semiconductor field-effect transistor
MIT: Massachusetts Institute of Technology
MPI: Max-Planck-Institute
MTJ: magnetic tunnel junction
NASA: National Aeronautics and Space Administration
NIST: National Institute of Standards and Technology
NREL: National Renewable Energy Laboratory
NRL: Naval Research Laboratory
NSF: National Science Foundation
OLED: organic LED
ONR: Office of Naval Research
ORNL: Oak Ridge National Laboratory
PARC: Palo Alto Research Center
PLED: polymer LED
PSU: The Pennsylvania State University
PV: photovoltaic
R&D: research and development
RET: Research Experience for Teachers
SNL: Sandia National Laboratories
SOI: silicon-on-insulator
SQUID: semiconducting quantum interference device
TCO: transparent conductive oxide
TEM: transmission electron microscopy
TFT: thin-film transistor
UC: University of California
UCLA: UC—Los Angeles

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fluoride, the material absorbed ~90% of visible and IR wavelengths. Mazur hypothesized that the band structure of the material was changed, causing absorption in the visible spectral region. Regular arrays of spikes observed under TEM were found to maintain their crystalline structure, but to have a high number of defects with 10^{20} sulfur atoms/cm^2 and 10^{17} fluorine atoms/cm^2. The sulfur atoms introduced states in the bandgap of silicon, and the concentration of S in these materials (about 1 atom in 1000) far exceeded what can usually be found in silicon.

A major application of thin silicon films, as discussed in Symposium A, is active-matrix arrays for displays or sensors. Research into the microstructure and structural process in disordered silicon has led to an understanding of the intricate role of hydrogen in amorphous silicon. Furthermore, evidence has been reported on the paracrystalline phase as a structural precursor of nanocrystalline silicon.

In the area of II–VI compound semiconductor photovoltaic materials, the application of CIGSS and CdTe technologies to lightweight, flexible, alternative substrates was discussed in Symposium H. In Symposium E, the major focus was on III-nitride semiconductors. This Symposium also presented research on SiC and diamond electronics while Symposium F presented research on oxide electronics. In the TCO area, $CuInO_2$ was doped *n*-type with Sn^{4+} and *p*-type with Ca^{2+}, representing the first TCO system where homojunctions should be possible.

Microelectronics

In a search for an environmentally friendly, fire-resistant, plastic-molding compound to encapsulate electronic components, A.A. Gallo (Dexter Electronic Materials) reported, in Symposium N, that molding compounds with transition-metal oxides provide exceptionally good high-temperature electrical reliability, and are less environmentally hazardous than antimony trioxide which is traditionally used as a flame-retardant.

As a part of integrated efforts on high-temperature MEMS research, scientists at NASA reported, in Symposium N, the development of ceramics- and precious metal-based advanced microsystem packaging technologies for high-temperature ≥500°C applications. This technology enables long-term testing and commercialization of harsh environment microsystems.

In Symposium Y, A. Elshabini (Univ. of Arkansas) addressed some of the issues of packaging MEMS. In addition to having the same packaging needs as electronic circuits, these micromachines also need their moving parts and feedthroughs protected, without limiting their motion. One issue is stiction—sticking due to friction—causing gears to bind up. Dicing the arrays into individual "chips" is difficult because use of a wafer saw could damage the delicate structures. Also, handling is made difficult because a vacuum grip for picking up the structures can also lead to damage. The greatest chal-

Technical Symposia

Electronic Materials

Symposium A	Amorphous and Heterogeneous Silicon-Based Films—2001
Symposium B	Molecular and Biomolecular Electronics
Symposium C	Electronic, Optical, and Optoelectronic Polymers and Oligomers
Symposium D	Advanced Materials and Devices for Large-Area Electronics
Symposium E	Wide-Bandgap Electronics
Symposium F	Transport and Microstructural Phenomena in Oxide Electronics
Symposium G	Luminescence and Luminescent Materials
Symposium H	II–VI Compound Semiconductor Photovoltaic Materials

Microelectronics

Symposium I	Wafer Bonding and Thinning Techniques for Materials Integration
Symposium J	Si Front-End Processing—Physics and Technology of Dopant-Defect Interactions III
Symposium K	Gate Stack and Silicide Issues in Si Processing II
Symposium L	Materials, Technology, and Reliability for Advanced Interconnects and Low-*k* Dielectrics
Symposium M	Chemical–Mechanical Polishing—Advances and Future Challenges
Symposium N	Microelectronics and Microsystems Packaging

Thin Films and Surface Phenomena

Symposium O	Mechanisms of Surface and Microstructure Evolution in Deposited Films and Film Structures
Symposium P	Dislocations and Deformation Mechanisms in Thin Films and Small Structures
Symposium Q	Femtosecond Materials Science and Technology
Symposium R	Morphology and Dynamics of Crystal Surfaces in Molecular and Colloid Systems
Symposium S	Fundamental Studies of Corrosion and Oxidation

Data Storage

Symposium T	Materials for Magnetic Devices—Magnetoelectronics and Recording
Symposium U	Ferromagnetic Materials
Symposium V	Optical Data Storage—Materials, Mechanisms, and Emerging Technologies

Nano- and Biomaterials

Symposium W	Nanotubes, Fullerenes, Nanostructured and Disordered Carbon
Symposium Y	Synthesis, Functional Properties, and Applications of Nanostructures
Symposium Z	Patterning Soft Materials—From Methods to Applications

General

Symposium AA	Advances in Materials Theory and Modeling—Bridging Over Multiple Length and Time Scales
Symposium BB	Material Instabilities and Patterning in Metals
Symposium CC	Nuclear Waste Containment Materials
Symposium EE	Applications of Synchrotron Radiation Techniques to Materials Science
Symposium FF	Materials Problem Solving with the Electron Microscope
Symposium GG	Impacting Society through Materials Science and Engineering Education
Symposium X	Frontiers of Materials Research

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lenge, Elshabini said, was that packaging needs are often application-specific.

In studies on gate structures required for sub-100-nm devices, presented in Symposium K, HfO_2 and ZrO_2 were the predominantly discussed high-permittivity materials on silicon. In the area of low dielectric constant materials and reliability, discussed in Symposium L, the effects of electroplating with additives on the microstructure of damascene Cu demonstrated the necessity of post-plating stabilization treatments.

In Symposium I, D. Dapkus (Univ. of Southern California) said that wafer bonding will be significant in the emerging field of optoelectronics because, for example, it enables the use of transparent substrates, mismatched heterojunctions, and access to the back side of a device late in processing, as demonstrated through prototypes.

Symposium J addressed the need for shallow junctions and dopant control for silicon technologies. Among the methods described were coimplantation of impurities, the optimization of rapid thermal annealing conditions, and the use of pulsed-laser annealing.

Neal D. Evans of Oak Ridge National Laboratory (second from the left) presented a poster on the Shared Research Equipment User Facility at Oak Ridge. Symposium FF showcased User Facilities during the poster session in order to demonstrate the work taking place at these facilities. Posters were also presented on the National Center for Electron Microscopy, the Center for Microanalysis of Materials, and the Electron Microscopy Center, all funded by the U.S. Department of Energy.

Thin Films and Surface Phenomena

Nobel Laureate N. Bloembergen (Univ. of Arizona) introduced the topic of femtosecond science and materials interactions in Symposium Q. He said that strongly focused femtosecond pulses of only nanojoule energy content can be used to create submicron damage spots in transparent materials by creating a plasma strongly localized in space and time. The quick disappearance of the pulse leaves the surrounding areas unaffected. Femtosecond pulses can be used to break bonds, to analyze, and to change shapes of molecules. A key application is in the formation of optical waveguides, using femtosecond pulses to create a slightly higher index of refraction. This technique can be used to direct-write single-mode optical waveguides.

Magnetic anisotropy has been used for many years in recording technology and information-storage applications. Epitaxial growth of magnetic thin films, as presented by R. Clarke (Univ. of Michigan) in Symposium O, introduces a twist on this property of magnetic materials. Clarke's group deposited two distinct crystalline forms of cobalt (fcc and hcp), each of which has very different magnetic switching fields. Quantum-mechanical tunneling between these two forms through a boron nitride barrier layer is the basis of a new logic/memory device.

In the study of dislocations in thin-film heteroepitaxial layers, presented in Symposium P, one goal is to reduce the density of threading dislocations in a relaxed layer. Modifying the substrate with a buried SOI layer or by implanting He into the substrate of a SiGe/Si system both produced significant dislocation reductions.

J. Frenken (Leiden Univ.), in Symposium R, described the role of steps and kinks in the game of diffusion at surfaces. He found that on copper (100) surfaces, atoms would sometimes move large distances almost instantly, and these motions would be correlated with other atoms doing the same thing. In Symposium S, K. Zavadil (SNL) demonstrated the ability to engineer specific oxide defects into an aluminum oxide and to determine their impact on electrochemical behavior.

Data Storage

In Symposium V, predictions were made that, in the second half of this decade, blue lasers and optics will be used to create storage capacities exceeding 100 GB for CD-size removable disks and that by the end of the decade, storage capacity nearing TB per disk will be achieved through techniques based on holography and multilayer phase-change media. Speakers in Symposium U addressed the role of disorder in nanostructured materials, which was related to the magnetic properties.

In the area of spintronics, discussed in Symposium T, one area of discussion was the topic of spins in semiconductors. Researchers debated over the material required to inject the spin into the semiconductor. B. Jonker (NRL) reported on a spin-LED for which a magnetic semiconductor was used for the injector.

For further details on the technical content of the Meeting, see the following symposium summaries. Proceedings are available on-line at www.mrs.org.

Improvement Demonstrated in Deposition Rate and Quality of Amorphous and Microcrystalline Silicon

(See MRS Proceedings Volume 664)

Symposium A opened with a full-day tutorial on the physics and technology of amorphous and microcrystalline silicon. The Meeting presentations following discussed significant progress that has been made in the high or even ultrahigh rate deposition of device-quality amorphous and microcrystalline silicon and in the state-of-the-art computer modeling of deposition processes. Both are important issues, especially for the future commercialization of silicon thin-film solar cells. These cells now approach stabilized conversion efficiencies of up to 10% even for large-area modules. Experimental and theoretical tools for the investigation of the microstructure and structural processes in disordered silicon have been

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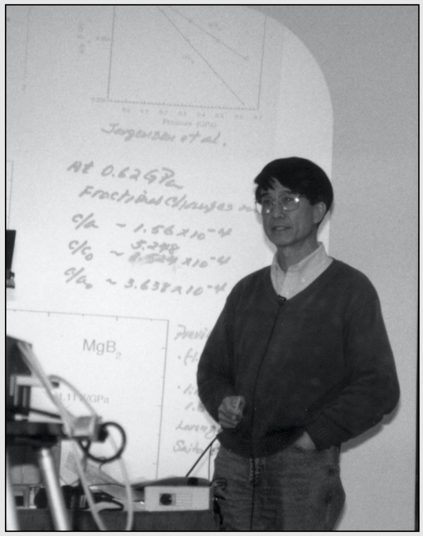
MRS Late-News Session Shows Rapid Development of MgB_2, a New Superconductor with T_c of 39 K

A special late-news session on the MgB_2 superconductor was held at the 2001 Materials Research Society Spring Meeting in San Francisco on Tuesday, April 17, 2001. The session emphasized fundamental materials and processing issues, challenges, R&D opportunities, and some exciting results.

The surprising discovery of 39 K superconductivity in crystallographically simple MgB_2 in January has launched a flurry of intense international R&D activities, as scientists search for higher transition temperatures (T_c) as well as a better understanding and improvement of MgB_2's materials characteristics. The superconducting transition temperature is lower for MgB_2 than for the high-temperature oxide superconductors and lower than liquid-nitrogen temperatures. In spite of this, MgB_2 has great appeal because it is easier to fabricate for applications.

With information on the properties of MgB_2 continuing to pour in through publications and Web site postings, positive news has appeared at the time of the MRS Meeting, such as an upper critical field (H_{c2}) value of as high as 39 T with a high irreversibility field; high critical current densities (J_c) for polycrystalline thin-film and bulk MgB_2 of the order of 10^6 A/cm^2 or higher; and successful fabrication of high-J_c films, wires, and fibers. These attributes make MgB_2 increasingly more attractive than either the low-T_c metallic superconductors or the high-T_c oxide superconductors. The substantially larger coherence length of ~50 Å in MgB_2 also makes it much easier to form reliable Josephson tunnel junctions as compared with only ~3 Å along the *c*-axis in the Y-Ba-Cu-O superconductor requiring critical dimensional and fabrication controls.



In an MRS late-news session on the rapid development of MgB_2 as a new superconductor with T_c of 39 K, keynote speaker Paul Chu (Univ. of Houston) described the correlation between MgB_2 material conditions and its magnetoresistance behavior.

Session Highlights

Paul Chu (Univ. of Houston), in his keynote presentation, discussed the correlation between MgB_2 material conditions and its magnetoresistance behavior, and the nature of pressure effect on T_c . He described the unusual but clear indication of broad diamagnetic transition beginning at ~120 K and extending to lower temperatures in one of the MgB_2 allomorphs. Chu said that further research is under way to identify the nature of the observation.

Douglas Finnemore (Ames Lab) described the very low normal-state resistivity and the electron mean free path in their high-purity, high-critical-current-density MgB_2 fiber segments prepared by exposing boron filaments to Mg vapor. He discussed the challenges of shortening the mean free path and the coherence distance to further raise the upper critical field. He also discussed the isotope effect, emphasizing the importance of in-plane boron phonons for high T_c .

David Larbalestier (Univ. of Wisconsin—Madison) presented an updated, global magnetic field versus temperature (*H–T*) phase diagram that indicates the overall useful application ranges for the MgB_2 superconductor. Based on the characterization of thin films grown in Chang-Beom Eom's group (Duke Univ.), which showed a marked *c*-axis texture, the researchers were able to measure the anisotropy in H_{c2} and observe the resistivity-dependence of H_{c2}. In high-resistivity films, H_{c2} parallel to the planes has now been raised to 39 T, more than twice the value seen in bulk MgB_2 and higher than that for the leading A15 conductor, Nb_3Sn. This, together with the inherently weak-link-free nature of the MgB_2 grain boundaries, offers increased promise for the material's potential in practical high-field applications.

Yimei Zhu (BNL) presented HRTEM results for the MgB_2 structure, clearly showing the positions of magnesium and boron atoms in the lattice. The nature and configurations of dislocations, precipitates, and other defects were also discussed. In the particular sample examined, ~30% of the grain boundaries contained a relatively thick, oxygen-rich amorphous layer.

Darrell Schlom (PSU) reported on the thermodynamics of and a calculated phase diagram for the Mg-B system. Due to the high volatility of magnesium, MgB_2 is stable at the relevant processing temperatures only under high Mg overpressure. The results and analysis provide helpful insights into the limitations and optimizations of processing conditions for MgB_2 thin-film and bulk material fabrication. The viability of film fabrication by various deposition techniques, such as laser ablation, MBE, CVD, and sputtering, was also discussed.

Sungho Jin (Lucent Tech/Bell Labs, Agere) described the successful fabrication of practical high-J_c, metal-clad ribbons of MgB_2. The iron-clad ribbon configuration allows the use of an ambient atmospheric pressure, without the cumbersome use of a Mg vapor environment, during sintering heat treatment to obtain very dense, bulk MgB_2 material with little vaporization loss of Mg. Some flux-pinning-enhancement results seem to indicate bulk J_c values of the order of 10^6 A/cm^2. It was also shown that while inherently strongly coupled, the MgB_2 grain boundaries are not immune to induced weak-link behavior by some foreign metallic elements.

Robert Kaindl (LBNL) reported on the results of ongoing joint research with Oak Ridge National Laboratory. He presented the first results of far-IR optical transmission studies of the MgB_2 films, probing fundamental low-energy excitations near the condensate and superconducting gap.

Adriana Serquis (LANL) reported on a large paramagnetic Meissner effect below T_c in field-cooled experiments, observed in their high-purity MgB_2 samples formed by reaction of boron with magnesium vapor, but not in commercially available MgB_2 samples.

Sang-wook Cheong (Bell Labs/Rutgers Univ.) reported an observation of slightly higher T_c (onset) of 41.1 K in the MgB_2 film formed by reacting a boron single-crystal surface with Mg

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Continued from page 563.

vapor, possibly creating a MgB_2 film under a tensile stress state. The implications were discussed with respect to the possible use of the substrate to induce MgB_2 lattice expansion and higher T_c by means of forced epitaxy or differential thermal contraction on cooling.

Additional items of interest presented in the session include the synthesis of hexagonal-shaped MgB_2 single crystals, ~20 µm in size for now (by H.N. Jones, NRL); *in situ* fabrication of MgB_2 films and the first fabrication of SQUID junctions (by David Blank, Univ. of Twente, The Netherlands); and the synthesis of MgB_2 nanofibers with dimensions and aspect ratios resembling single-walled carbon nanotubes, using the catalyzed laser ablation process (by P. Yang, UC-Berkeley).

Interestingly, at the time of the MRS Meeting, two popular sources of MgB_2 powder in the United States reported that they were completely out of the material (not even 10 g left), and many researchers had to wait at least six weeks to receive their ordered MgB_2 powder material.

For Further Information

1. J. Nagamatsu, N. Nakagawa, T. Muranaka, Y. Zenitani, and J. Akimitsu, *Nature* **410** (2001) p. 63.
2. D.C. Larbalestier, L.D. Cooley, M.O. Rikel, A.A. Polyanskii, J. Jiang, S. Patnaik, X.Y. Cai, D.M. Feldmann, A. Gurevich, A.A. Squitieri, M.T. Naus, C.B. Eom, E.E. Hellstrom, R.J. Cava, K.A. Regan, N. Rogado, M.A. Hayward, T. He, J.S. Slusky, P. Khalifah, K. Inumaru, and M. Haas, *Nature* **410** (2001) p. 186.
3. D.K. Finnemore, J.E. Ostenson, S.L. Bud'ko, G. Lapertot, and P.C. Canfield, *Phys. Rev. Lett.* **86** (2001) p. 2420.
4. C.B. Eom, M.K. Lee, J.H. Choi, L. Belenky, X. Song, L.D. Cooley, M.T. Naus, S. Patnaik, J. Jiang, M. Rikel, A. Polyanskii, A. Gurevich, X.Y. Cai, S.D. Bu, S.E. Babcock, E.E. Hellstrom, D.C. Larbalestier, N. Rogado, K.A. Regan, M.A. Hayward, T. He, J.S. Slusky, K. Inumaru, M.K. Haas, and R.J. Cava, "Thin Film Magnesium Boride Superconductor with Very High Critical Current Density and Enhanced Irreversibility Field," preprint, Los Alamos National Laboratories Preprint Server, http://lib-www.lanl.gov/libinfo/preprints.htm, cond-mat/0103425 (accessed May 2001).
5. R.J. Cava, *Nature* **410** (2001) p. 23.
6. A.M. Campbell, *Science* **292** (2001) p. 65.
7. Los Alamos National Laboratory's Condensed-Matter Web site (http://xxx.lanl.gov/archive/cond-mat) contains many posted manuscripts on MgB_2 as submitted by authors (accessed May 2001).

greatly refined, leading to insights into the intricate role of hydrogen in amorphous silicon. Also, strong evidence has been provided for the so far elusive "paracrystalline" phase as a structural precursor of nanocrystalline silicon. Active-matrix arrays for displays or sensors continue to be the second major application of thin silicon films, and a lot of progress has been made in those areas. In addition, novel concepts for the use of amorphous or microcrystalline silicon in sensors, bio-implants, or micromechanics were presented.

Symposium Support: Akzo Nobel nv; dpiX, LLC; Fuji Electric Company; NREL; Sanyo; United Solar Systems; Voltaix; and Xerox PARC.

Connecting Molecules and Electronics
(See MRS Proceedings Volume 679E)

Innovative fabrication techniques for the formation of nanostructures continue to emerge. A view was expressed in Symposium B that molecular electronics would do well to determine the properties of molecules and molecular clusters, and find ways to incorporate these unique properties into microelectronic/nanoelectronic devices and systems. Early emphasis on a device (e.g., transistor) comprising only a single molecule has been markedly de-emphasized. The issue of how to connect molecular units together to make complex devices remains a difficult and unanswered question. One speaker emphasized that machine architecture must be stable and exact in order to be "robust."

The hysteresis of current-voltage behavior of isolated molecular layers (with submicron lateral dimensions) was reported in several presentations. Somewhat surprising was the observation that such hysteresis behavior may be observed for "about 2/3 of the molecules in the Aldrich catalog," an observation that could conceivably be explained by a dielectric material trapping a charge. Just what is being observed, and the material characterization, represents an issue for which there is far from unanimous agreement.

Self-assembly continues to represent an intriguing opportunity for the fabrication of nanostructures. Arrays of nanocrystals are produced with increasing control over long-range order, which is of interest for the storage and retrieval of information. Researchers have shown that carefully isolated peptides selectively bind to various semiconducting materials, demonstrating a substantial influence on structure and dimensions of nanocrystal formation.

Biomolecular and nanostructures reveal many applications for sensing, biological and medical diagnostic procedures, and new biocompatible materials. The synergy of both biomolecular phenomena and molecular electronics, taken together, should be most beneficial.

Kristi S. Anseth of the University of Colorado (right) accepts the Outstanding Young Investigator (OYI) Award as presented by MRS President Marty Green (Lucent Tech/Bell Labs, Agere). During her OYI presentation, Anseth described work by her group on photopolymerizable polymers for use as biomaterials.

Synthesis and Processing Affect Molecular Optoelectronics
(See MRS Proceedings Volume 665)

Symposium C showed advances made in the areas of organic electroluminescent materials and devices, photovoltaic materials, and FET technologies. Improved mobilities, on/off ratios, and integration have been demonstrated. There is recognition that molecular optoelectronics is not only a materials-limited field but that it is also affected greatly by processing conditions. In this regard, a number of talks focused on fundamental structure–property relationships as well as processing approaches. Chemical synthesis of fundamental new materials was represented. Building upon the fact that the highest performance FET materials have a polyacene structure, F. Wudl (UCLA) reported the design and study of an unusual class of molecules containing donor (nitrogens) and acceptor (carbonyl) groups. Wudl's molecules display peculiar properties due to their tendency to distribute charge in a way that perturbs the typical aromatic character and three-ring acenoid systems display bandgaps similar to pentacene. This approach promised to provide synthetic access to materials with the superior properties expected from higher acenes. M. Thompson (Univ. of Southern California) introduced efficient blue electrophospho-

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rescent material that can be used in flat-panel displays. G.E. Jabbour (Univ. of Arizona) introduced organic-based LEDs and solar cells processed by screen printing. He demonstrated the use of this technique to print organic layers with thicknesses as low as 20 nm. The merging of conducting polymers with other diverse functionality was also a target of a number of investigators. P. Skabara (Manchester Univ.) described the synthesis of a number of thiophene monomers and polymers that contain electron donating tetrathiafulvalene-like elements, thereby bridging the gap between molecular and polymeric metals. Hybrid materials between regioregular polythiophenes and DNA were highlighted by M. Leclerc (Laval Univ.). In Leclerc's schemes, the interactions of DNA with cationic polymers can be used as a transduction element for the hybridization with a complementary strand of DNA. Upon binding its complement, the associated polythiophenes were transformed from a nonemissive to emissive form, thus providing a highly sensitive transduction scheme. Innovative molecular mechanisms for polymer actuation were presented by M. Marsella (UC—Riverside). In these schemes, oxidation of the polymers produced geometric changes in cyclic thiophene units that change the molecular dimensions of the materials. Such schemes promise to produce artificial muscles that are capable of increased dimensional changes while providing large forces, two features that are mutually exclusive in most conventional actuator materials. There is considerable interest in the study of C_{60} mixtures with conjugated polymers for applications in photovoltaic devices. Elegant fundamental photophysical studies involving discrete oligothiophenes with covalently bound C_{60} groups by R. Janssen (Eindhoven) revealed that in some cases the mechanism for charge injection is not necessarily an initial electron transfer from the polymer to the C_{60}, as is often assumed.

Graduate Students Receive Gold and Silver Awards

During the 2001 MRS Spring Meeting, graduate student finalists received Gold and Silver Awards.

Gold Awards went to (first row, left to right) **Maura Jenkins** (Stanford Univ.); **Christine E. Flynn** (The Univ. of Texas—Austin); **Suneel Kumar Kodambaka** (Univ. of Illinois at Urbana-Champaign); **Ning Cheng** (Univ. of California—Berkeley); and **Emily Jarvis** (Univ. of California—Los Angeles); and (second row, left to right) **Jonathan Baugh** (Univ. of North Carolina—Chapel Hill); **J. Tobias Lau** (Univ. of Hamburg, Germany); **Daniel Kammler** (Northwestern Univ.); **Brian Hubert** (Massachusetts Institute of Technology); and **Shriram Ramanathan** (Stanford Univ.).

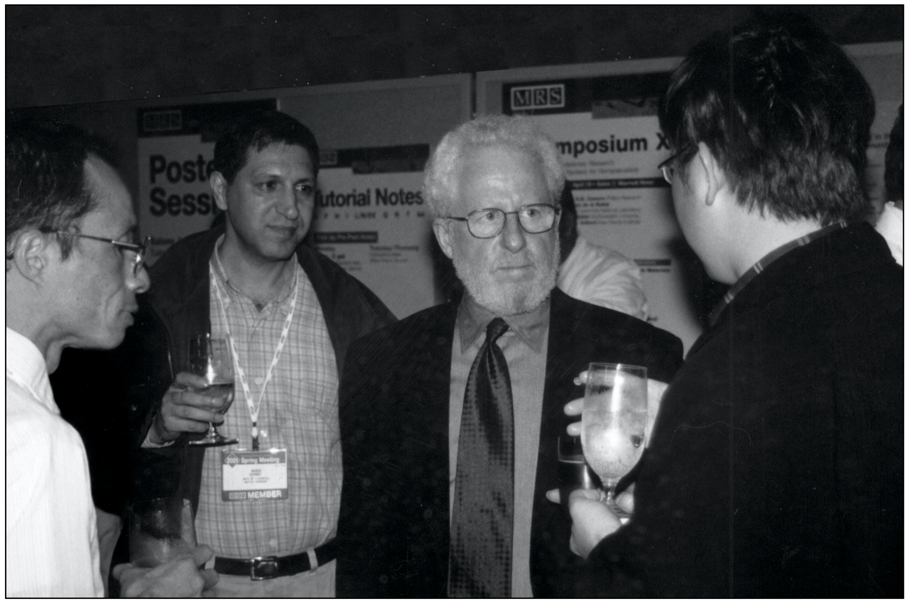
Silver Awards went to (first row, left to right) **Cora Lind** (Georgia Institute of Technology); **Greg Kusinski** (Univ. of California—Berkeley); **Jie Zou** (Univ. of California—Riverside); **Ching-Yin Hong** (Massachusetts Institute of Technology); **Camelia Borca** (Univ. of Nebraska); **Satoshi Shimizu** (Electrotechnical Laboratory, Japan); **Colin Bulthaup** (Massachusetts Institute of Technology); and **Mark E. Overberg** (Univ. of Florida); and (second row, left to right) **Susan Gillmor** (Univ. of Wisconsin—Madison); **Hyun-Chul Jin** (Univ. of Illinois at Urbana-Champaign); **Alessandro Romeo** (Swiss Federal Institute of Technology, Switzerland); **Ming Zhang** (Univ. of Illinois at Urbana-Champaign); **Ageeth A. Bol** (Utrecht Univ., The Netherlands); **Natasha Erdman** (Northwestern Univ.); and **Robert W. Meulenberg** (Univ. of California—Santa Barbara).

Large-Area Electronics Benefit from Recent Advances in the Formation of Polycrystalline Silicon Films

(See MRS Proceedings Volume 685E)

Symposium D provided a forum for idea exchanges among researchers working in several areas of large-area electronics (LAE), such as displays and solar cells. The microstructural optimization of the active layer (silicon) drives the performance of devices used in LAE applications. Recent process advances and breakthroughs allow the precise engineering of the microstructure of thin polycrystalline silicon films, crystallized by laser annealing. Such films enable the fabrication of devices that can fit a wide range of applications in LAE. J.S. Im and his co-workers at Columbia University discussed the application of the so-called sequential-lateral-solidification (SLS) process as a means to precisely tailor the microstructure of poly-Si films. Using SLS technology, structures ranging from medium-quality polycrystalline material to SOI-like material can be achieved by exploiting the specific features of laser-induced lateral growth. Such lateral-growth methods can also be applied to enhance the performance of Si films for solar-cell applications, according to a presentation by the group from the Universitat Erlangen-Nurberg in Germany. One alternative to laser-induced crystallization was presented by J.H. Werner and his co-workers at the University of Stuttgart. This concept is based on joined-wafer Si whereupon Si thin films are transferred from a "master" substrate to glass or other substrate, depending upon the application. Werner proposed a method that allows such transfer to take place over large areas, opening the possibility of using his concept for LAE. The LCD-TFT industry has adopted low-temperature poly-Si technology driven by the rapidly growing market of mobile communication products, as M. Adachi (Sharp Corp.) explained in his presentation. The LCD industry is rapidly moving along a very aggressive technology roadmap, according to the presentation of T. Nishibe (Toshiba). To meet the targets of this roadmap, lateral-growth technology is needed for the formation of polysilicon. Such realization has also sensitized equipment manufacturers, who are already developing the necessary optical components (as described by H.J. Kahlert of MicroLas) and the next generation of powerful excimer lasers (as described by V.M. Borisov of State Research Center of Russian Federation) to meet this demand. C. Curtin (Candescent Technologies) operated one of the company's 5.3 in. Diagonal Thin CRT™ displays which was nicely integrated into a DVD player. Meeting attendees could directly compare their own laptop computer displays. The substantial improvement is due to the use of P-22 phosphors operated at relatively high voltage, 8 kV. Other design highlights of the field-emission display include 0.12-μm gate holes fabricated by ion tracking as well as resistive material formulations and special coatings to prevent charging. J.A. Panitz (Univ. of New Mexico) and A.L. Akinwande (MIT) suggested additional applications for field emitters in their talks.

Symposium Support: HP and LLNL.



Following his plenary address, Nobel Laureate Alan J. Heeger of UC—Santa Barbara (second from the right) continues his discussion with meeting attendees during the plenary reception. The topic of Heeger's presentation was semiconducting and metallic polymers.

Fundamentals and Device Applications of Wide-Bandgap Semiconductors Discussed

(See MRS Proceedings Volume 680E)

Symposium E on the latest developments in the field of wide-bandgap semiconductors for electronic applications addressed the key areas of material growth, material and defect characterization and modeling, and device processing and characterization. Presentations on III-nitride semiconductors were a major focus of the Symposium, with research on SiC and diamond electronics also well represented. The Symposium opened with invited overview talks by S. Allen (Cree) and D. Laighton (Raytheon) who described commercial and defense applications for this technology, respectively. These talks served to highlight the potential benefits of wide-bandgap electronic devices and provided the motivational focus for the research needed to mature this technology. Invited talks by L. Eastman (Cornell), E. Kohn (Univ. of Ulm), P. Asbeck (UC—San Diego), and U. Mishra (Cree), as well as Y. Wu (Cree Lighting) summarized the current state of devices and material technology based on III-nitrides. They offered novel approaches to address fundamental material, process, and device challenges, including materials engineering of piezoelectric and spontaneous polarization effects and utilization of InGaN ternary alloys. Other presentations focused on the characterization of defects and various phenomena that limit device performance (e.g., current slump and dispersion). In addition, some speakers described recent developments in wide-bandgap substrate materials, and some addressed doping and ohmic contact formation, which are critical for the fabrication of wide-bandgap MESFETs, HEMTs, and HBTs. Researchers from Wright State University presented several posters on the use of wide-bandgap materials for biomedical applications.

Symposium Support: Sula Tech., Cree Lighting, and Raytheon.

Doping of Oxide Conductors Examined

(See MRS Proceedings Volume 666)

In Symposium F, there was a very active discussion on transparent conducting oxides, with a focus on *p*-type materials. Initial results on the *n*-doping of ZnO to produce *p*-type ZnO are proving to be very difficult to reproduce. There may only be a very small region of phase space where this doping approach is possible. The mechanism of the *p*-type doping of ZnO and of the doping of *n*-type TCOs was discussed at length by a number of speakers. Despite tremendous technological impact, very little of the basic science of the TCOs is understood. Theory results provide a number of models for doping, which, if verified, could lead to improved materials. One of the most exciting results in the TCO area was the report of $CuInO_2$ from the Tokyo Institute of Technology where the material was doped *n*-type with Sn^{4+} and *p*-type with Ca^{2+}, demonstrating a TCO system where homojunctions should be possible. Ferroelectric materials are another family of materials with tremendous current and are emerging in the area of DRAM and frequency agile microwave electronics. A number of presentations addressed methods of controlling the interfacial properties of ferroelectric materials such as $BaSrTiO_3$ on a variety of substrates. A number of groups are approaching atomic-level control of interfaces allowing for the deposition of high-quality materials on substrates as diverse as Si and MgO. Em-

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bedded strain from the growth process for the ferroelectric materials and other oxide systems has also been demonstrated to be a critical determinate of the film properties. A model for ferroelectric materials showed that a nanopolar reorientation transition may be responsible for the marked increase in dielectric tuning for nonstressed films.

Symposium Support: NREL.

Luminescence Shines Broadly

(See MRS Proceedings Volume 667)

In Symposium G on luminescent materials, the main themes ranged from theory and modeling to characterization of luminescent materials, systems with confined structures such as nanocrystallites and quantum wells and dots, and synthesis and devices.

Symposium Support: OSRAM Sylvania and eMagin Corp.

II-VI Solar-Cell Research Concerned with Flexible Substrates, Interfaces, and Defects

(See MRS Proceedings Volume 668)

Symposium H focused on materials issues related to $Cu(In,Ga)(Se,S)_2$ (CIGSS) and CdTe-based polycrystalline thin photovoltaic solar cells, and related oxides and chalcogenides. In the area of materials and synthesis, phase equilibrium and thermochemical kinetic aspects of the absorber layer formation of CdTe and CIGSS were emphasized, followed by a discussion of a variety of deposition methods and monitoring techniques. Several papers reported on microanalytical analysis, which revealed detailed structural properties of the thin films.

In the area of substrates, several papers emphasized the use of flexible plastic or metal foil substrates. Issues addressed were the performance and limitations imposed by the nature of the flexible substrates, and ways to overcome the limitations. The influence of electron and proton irradiation on the solar-cell performance for space applications was also presented.

A. Zunger and S.H. Wei of the National Renewable Energy Laboratory discussed point defects in PV materials, including fundamental principles of the formation energy of intrinsic defects in chalcopyrites and II–VI materials. They discussed how defects stabilize themselves, addressed doping limitations, and covered how this research could guide experiments and analysis.

In terms of surfaces and interfaces, the properties of defects and interfaces in CdTe and CIGSS were highlighted, using electrical, optical, and microanalytical tools. The film properties were correlated to device physics.

In terms of film/device characteristics, some controversy still exists on the detailed operation of both the CdTe and CIGSS devices as several speakers presented their views based on recent results.

Two discussion sessions were held during the week. The first focused on exploring the application of the CIGSS and CdTe technologies to lightweight, flexible, alternative substrates. J. Merrill opened this session with an introduction of issues that the Air Force Laboratory and NASA have highlighted as criteria for thin-film solar cells for space application. The second session focused on the nature of junctions in devices. Evidently, the junction chemistry and physics are still not understood, but the junction/device performance may not be overly sensitive to this chemistry.

Symposium Support: NREL, BP Solar, Siemens Solar Industries, AFRL /VSSV, ITN Energy Systems, and Inst. of Energy Conversion at the Univ. of Delaware.

Wafer Bonding and Precision Thinning Accelerate Move to Stack Layers of "Anything on Anything"

(See MRS Proceedings Volume 681E)

Symposium I, a new Symposium for the MRS Spring Meeting, presented a central theme of integrating disparate materials. The presentations spanned a range of topics from fundamental physics and chemistry of wafer bonding and precision thinning to commercialization of specific products. Advanced wafer-thinning techniques such as hydrogen implantation and laser liftoff, described respectively by B. Aspar (CEA/LETI) and W. Wong (Xerox), now enable precision thinning of a great variety of materials. They suggest there is a realistic possibility to stack layers of "anything on anything," a phrase that was used repeatedly during the Symposium. These advanced splitting techniques bring to the fore a number of scientific issues that are unresolved, especially related to fracture, stress, and point and extended defects. While a keynote presentation by J. Haisma (Philips, retired) showed that direct wafer bonding goes back at least to the time of Isaac Newton, another talk in the same session by P.D. Dapkus (Univ. of Southern California) demonstrated that bonding is also a method with a future and will play a significant role in the emerging field of integrated optoelectronics. Dapkus showed numerous working examples of prototype devices that can only be fabricated with wafer bonding because it permits the use of transparent substrates, mismatched heterojunctions, and access to the back side of the device late in processing. In an invited talk, S. Noda (Kyoto Univ.) described several exciting breakthroughs that have allowed his group to produce full 3D photonic crystals by repetitive bonding of striped III–V structures.

Symposium Support: Canon, SOITEC SA, LANL, ORNL, Applied Optoelectronics, and Silicon Genesis.

Students take the opportunity to mingle at the Student Mixer, hosted by the 2001 MRS Spring Meeting.

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Dresselhaus Discusses Participation of Women in Science and Engineering

Mildred Dresselhaus of the Massachusetts Institute of Technology (MIT), guest speaker at the Women in MRS Breakfast, speculated on the position of women in science and engineering. She addressed the growing proportion of women working in science and engineering since 1970, and the role that interventions played in this increased participation. She also gave some perspectives on the future status of women in the field of materials science and engineering.

Dresselhaus provided numerous statistics exemplifying the progress made in increasing the number of women in science since 1970. When MIT implemented a program to aggressively attract women to the science departments, the Institute saw a rise in the number of women undergraduate students. The program included interventions as simple as students actively contacting newly accepted applicants. This direct contact would pull women into the educational program.

In a Survey of Doctorate Recipients conducted by the U.S. National Science Foundation, a graph of the number of full-time doctoral science and engineering faculty, by rank and sex, demonstrates that between 1973 and 1995, the number of women faculty from junior to full professor has remained below the number of male professors of all ranks (see Figure 1). Since 1994, the Committee on Women Faculty in the MIT School of Science has reviewed issues such as salary; grant funds; percentage of academic year salaries brought in on grants; start-up funds; allocation of departmental resources; teaching loads; participation on search committees; inclusion on important departmental committees of governance and policy; chairs, awards, nominations for internal and external awards; and use of maternity/family leave and delays in the tenure clock. The effect of this intervention has been a steady improvement in the status of the senior women faculty members in the areas under discussion, and improvement in the morale of the women faculty and of the graduate students and the postdocs.

The School of Science furthermore showed an increase of women faculty (tenured and untenured combined) of 5% between 1994 and 2000, in which women made up 8% of the faculty in 1994, to 13%. In the School of Engineering, women make up 17% of the faculty in the Department of Materials Science and Engineering, as of last year (see Table I). This is superseded by the School of Science in the Department of Biology—in which women make up 22% of the faculty—and the Department of Brain and Cognitive Science—in which they make up 26% of the faculty. In the Department of Physics, women constitute 7% of the tenured and untenured faculty.

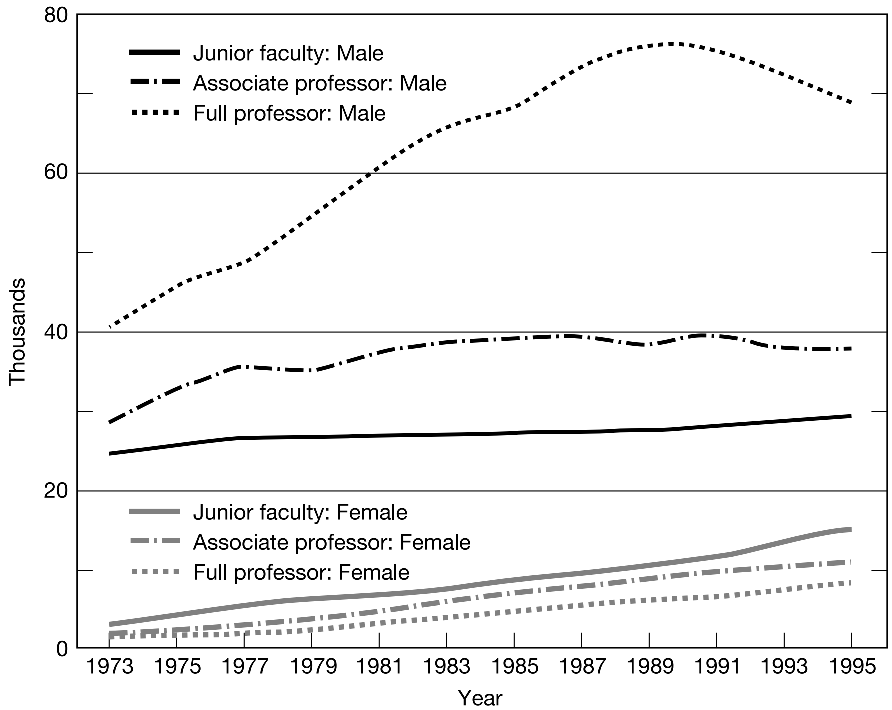

Figure 1. Full-time doctoral science and engineering faculty, by rank and sex. Note that junior faculty members are either assistant professors or instructors. Source: 1998 National Science Foundation Science and Engineering Indicators. The report can be accessed at www.nsf.gov/sbe/srs/seind98/start.htm.

Dresselhaus showed numbers, as of 1999, in which there are 43.3 female students per female faculty whereas there are 10.8 male students per male faculty (in engineering). Among the recommendations of Gender Equity in Academic Science and Engineering Convocation at MIT on January 29, 2001 was to increase the number of women faculty so as to reflect the number of women students, and to ensure full participation of the women faculty across the spectrum of faculty activities.

This event was organized by the Outreach Subcommittee within the MRS Public Affairs Committee.

Table I: Percent/Number of Female/Male Faculty by Department at MIT—2000*

Female Faculty as a Percent of Total	Number of Tenured Female	Number of Tenured Male	Number of Untenured Female	Number of Untenured Male
17% Materials Science & Engineering	4	26	2	3
22% Biology	7	29	4	9
26% Brain & Cognitive Science	5	11	1	6
7% Physics	3	52	2	12

* Numbers are extracted from the original source. The primary data was obtained from Lydia Snover, Assistant to the Provost for Institutional Research, MIT. The numbers should be considered unconfirmed because data may have been collected at varying times during the year.

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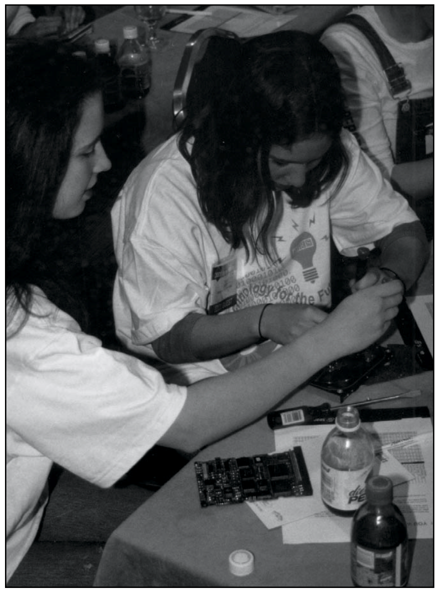
Dopant-Defect Control Needed for Shallow Junctions

(See MRS Proceedings Volume 669)

Symposium J was the third in a sequence of symposia covering the subject of Physics and Technology of Dopant-Defect Interactions in Si Front-End Processing. The theme of the Symposium was set on the first day by a series of invited papers addressing the need for shallow junctions and dopant control for future silicon technologies. A considerable part of the Symposium was aimed at unraveling the complex potpourri of atomistic processes that are activated during annealing of ion-implanted dopant atoms. Various papers attested to the impressive level that has been reached over recent years in the understanding of how ion-generated vacancies and interstitials evolve through the formation of clusters and extended defects during annealing. These and other insightful experimental results have significantly improved the ability with which dopant, defect, and impurity profiles can be predicted through numerical simulations. Transient-enhanced diffusion and dopant clustering severely hinder the formation of shallow, low-resistive junctions, in particular for *p*-type dopants. Furthermore, sputtering effects have been found to restrict the efficiency with which dopants are introduced into silicon at low implantation energies (e.g., 0.2 keV B). At the Symposium, various approaches to improving junction performance were presented and discussed, among which were the co-implantation of impurities such as fluorine, the optimization of rapid thermal annealing conditions, and the use of pulsed-laser annealing. These methods clearly hold promise for meeting the future industry needs, but further tailoring of the dopant-defect interactions is needed to ensure successful implementation into silicon processing.

Symposium Support: Agere Systems, Intel, Applied Materials, Fujitsu, Axcelis Tech., and Varian Semiconductor Equipment Assoc.



Two San Francisco high school students disassemble a hard drive during a student workshop sponsored by the Outreach Subcommittee of the MRS Public Affairs Committee at the 2001 MRS Spring Meeting. Sining Mao of Seagate Technology led the workshop titled Technology for the Future.

U.S. Government Agencies Present Grant Opportunities in Materials Research

MRS continued its tradition of presentations from grant-providing U.S. government agencies. From the National Science Foundation (NSF), W. Lance Haworth, executive director of the Division of Materials Research, emphasized the importance of the education component in research proposals. NSF focuses on academic institutions with the goals of advancing the fundamental understanding of materials and to prepare the work force. While Haworth's division is in the Directorate of Mathematical and Physical Sciences, other directorates also support materials research. NSF provides $300 million annually for materials research. While the latest presidential request amounts to a flat budget, Haworth said that NSF will continue its focus areas on nanoscale research, information technology, biocomplexity and environment, and science education with links to the importance of mathematics.

Steven G. Wax, deputy director of the Defense Sciences Office at DARPA, defined his agency's mission as to enable revolutionary innovation in the Department of Defense (DoD). DARPA supports research that is of high risk, a nontraditional approach, shows feasibility but is not obvious, and addresses a perceived need whereas other DoD areas support research that addresses a specific materials requirement. Some areas of research supported by DARPA include microsystems; information; materials; and the intersection of biology, information, and microsystems. Like NSF, various divisions within DARPA support materials research. For more information, access www.darpa.mil and www.nsf.gov/mps/dmr.

Gate Structures Stack Up to Scrutiny

(See MRS Proceedings Volume 670)

Speakers in Symposium K discussed gate structures needed for sub-100-nm devices. Several talks presented the latest results in high-permittivity materials on silicon. HfO_2 and ZrO_2 were the predominant materials. J. Robertson (Cambridge Univ.) presented calculations of the expected band offsets of many of the materials of interest. An excellent presentation highlighting the integration issues and cross-contamination concerns of processing high-κ gate dielectrics in a production fab was given by A.K. Agarwal (SEMATECH). M.A. Gribelyuk (IBM) demonstrated that Zr silicidation of ZrO_2 in direct contact polysilicon can be avoided by changing the poly deposition process. T.K. Higman (Minnesota Univ.) compared various techniques for characterizing high-permittivity capacitors and found that the traditional Terman technique gives optimistic values for the interface state density compared to other methods.

In the area of self-aligned silicide formation, C. Cabral (IBM) described techniques for *in situ* characterization of the growing silicide during the reaction process. This talk included some exciting depictions of the reaction. The issue of silicide material choice and the effect of Ti and TiN capping layers for deeply scaled devices was discussed at length. Although CoSi is the clear favorite, interesting new results on laser-annealed $TiSi_2$ presented by S.Y. Chen (National Univ. of Singapore) suggest that it may still be usable at very narrow dimensions under the right conditions. Nickel silicide was also discussed by several speakers.

Symposium Support: Motorola, Jordan Valley AR, and Applied Materials.

Sticking with Copper and Holey Dielectrics Requires Understanding Structure–Property Relationships

Symposium L featured materials, structure–property relationships, and reliability issues in the integration of low-*k* dielectrics and Cu in dual damascene architectures. The mechanical behavior, especially elastic and fracture properties, of polymer and porous low-*k* dielectrics was recognized as key to integration. New approaches to increase porosity while maintaining mechanical strength were presented for both spin-on and CVD dielectrics. A session on characterization of porosity in these materials, encompassing positron annihilation lifetime spectroscopy, positron decay, surface acoustic wave, and x-ray scattering measurements, elicited active discussion. Similarly important is an understanding

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Materials Education Workshop Views Research Experience for Teachers (RET) Programs at a Practical Level

At the 2001 MRS Spring Meeting, school science teachers joined representatives from 26 universities, the National Science Foundation (NSF), and other educational organizations to discuss the past and future of the Research Experience for Teachers (RET) programs sponsored by NSF. Through the RET programs, teachers spend several weeks—primarily during the summer—working side by side with professional researchers and graduate students on a research project. RET programs strive to bring science teachers and scientists closer together for the purpose of inspiring the content of the school curriculum with topical science issues. In this way, materials science reaches young people who typically experience science through the traditional courses such as biology, chemistry, and physics.

The goal of the workshop within Symposium GG on materials education was to bring together RET players to share ideas and learn from one another, since the structure and approaches of the programs vary. Early in the workshop, Sam Spiegel, of the Center for Integrating Research & Learning at the High Magnetic Field Laboratory in Florida, set the stage for the proceedings by suggesting that science and science education are often in two different worlds. Yet the number of students who choose to pursue advanced study and careers in science is related to the ability of teachers to engender curiosity in their students and make science relevant for them. RET programs help teachers do this by making them part of a cutting-edge research project, (re)piquing their curiosity as well.

Additional speakers described methods for evaluating RET programs and ideas for using materials in secondary education. Many universities are developing short courses (modules) on materials for incorporation into a classroom. Modules are often designed with assistance from teachers who lend their classroom knowledge to the project and then later test the modules with their students, thereby providing the feedback that the developers need. Northwestern University's Materials World Modules program, for example, allows teachers to complete evaluations on-line (see *MRS Bulletin*, March 2000, p. 90).

Throughout the afternoon, the participants tackled difficult issues: How can the RET experience be integrated into the classroom? How can the structure of RET programs reflect the challenges of time and money constraints that teachers face in their schools? Four discussion groups on RET program organization, promotion, goals and follow-up, and evaluation addressed these questions. Unlike other workshops that often assess programs from a big picture perspective, the presence of the teachers ensured that the discussions reflected real issues in the schools. For example, the discussion on program goals and follow-up underscored the fact that the teachers have different goals from one another for their summer research experiences. While many are looking for ways to revitalize their curriculum, others are primarily interested in conducting research. The teachers demonstrated that there is no "one size fits all" program.

The organizers of this session expect that these types of discussions are bound to change the way science education happens in the schools. Furthermore, by bridging the gap between scientists and science teachers, students will be the beneficiaries.

Researchers and high school teachers participate in topical discussion groups addressing the Research Experience for Teachers (RET) programs sponsored by NSF.

of interactions at interfaces between low-*k* dielectrics, diffusion barriers, and Cu and their impact on adhesion and reliability. The challenge of depositing conformal but increasingly thin diffusion barriers was addressed in several talks on atomic layer deposition of Ta, Ti, and their nitrides. Insights into the latent effects of electroplating with additives on the microstructure of damascene Cu highlighted the importance of post-plating stabilization treatments. Although Cu has superior electromigration performance compared with Al, talks noted the existence of dual failure modes and the importance of the early failure contribution in reliability of submicron dual damascene structures. In wider (i.e., upper level) lines, void formation was observed under a biaxial stress condition distinct from the usual near-hydrostatic stress condition in narrow lines. A joint session with Symposium N highlighted common themes in mechanical and adhesion issues faced in interconnect integration, chip passivation, and packaging. The Symposium was preceded by a tutorial on "Advanced Techniques for Materials Characterization and Reliability Testing," held jointly with Symposia N and EE.

Symposium Support: Dow Corning; ASM Intl N.V.; IBM—Almaden Research Center; Agere Systems; Novellus Systems; Shipley Company, L.L.C.; Dow Chemical, JSR Microelectronics, and Applied Materials.

Plastic Deformation in Confined Geometries Combines Complicated Dislocation and Grain-Boundary Mechanisms

(See MRS Proceedings Volume 673)

It is known that the plastic properties of thin films and mesostructures can differ greatly from those in the corresponding bulk material. The additional complications arising from the interactions between dislocations, grain boundaries, and material interfaces make this kind of problem even more difficult to understand than plastic flow in bulk materials. Since the topic is of importance both in front-end (e.g., heteroepitaxial semiconductor films and device processing) and in back-end (e.g., thin metal films) technology, Symposium P sought to bring together work from these various areas to review the current level of the overall understanding.

The most enthusiastically pursued topic was the response of thin metal films to various kinds of loading, with particular emphasis on Cu metallization currently used in microelectronic ICs. The experimental side of this field is advancing rapidly, as a variety of techniques for loading such films under well-controlled conditions were reported. These were supplemented by a number of detailed TEM studies of dislocation behavior. The theoretical interpretations of the increasingly well-characterized response behavior are still mainly qualitative and phenomenological, although recent advances in modeling the effects of diffusional relaxation in unpassivated films opened avenues.

The most interesting developments in the area of heteroepitaxial layers relate to schemes that reduce the density of threading dislocations in a relaxed layer by modifying the substrate. Introducing a buried SOI layer or implanting He into the substrate of a SiGe/Si system both seem to produce a marked reduction. The He implantation technique shows particularly impressive results. The interpretation of these results is in need of refinement.

The Symposium demonstrated the increasing use of dislocation dynamics simulations to attack the complicated task of connecting observation with the theoretical models. A number of groups are developing dislocation codes, and the Symposium saw several demonstrations that complicated examples of dislocation behavior are quantitatively reproduced by such simulations. With the addition of these techniques, our understanding of plasticity in confined geometries is projected to grow rapidly, and in a more integrated way, as experimental investigations, numerical simulations, and theoretical modeling are applied together to sort out the mechanisms at work in these complicated systems.

Symposium Support: IBM T.J. Watson Research Center, JEOL USA, FEI, Agere Systems, and MTS-Nano Instruments Innovation Center.

Thoughts Crystallize on the Morphology of Medicinal, Molecular, and Semiconductor Materials

Symposium R provided a forum for discussions and exchange between several communities, including structural and molecular biologists, medicinal and pharmaceutical chemists, geochemists and biomineralization scientists, and semiconductor and epitaxy physicists. These groups were brought together by the realization that the structures of the interfaces between crystals and other ordered or disordered assemblies and their nutrient media, and the ensuing dynamics of nucleation and molecular attachment, underlie the pathways and the rates of a number of phase-transformation processes. In all of these areas, the understanding of surface morphology and kinetics requires consideration of intermolecular interactions, possible molecular anisotropy, and structures arising on the interface between the nutrient and growing phases.

The Symposium started with a session of nucleation that counterpoised analytical theories, numerical simulations, and experiential determinations of the nucleation rates and the factors that affect them. In a joint session with Symposium O on surface thermodynamics, atomic, capillary, transport, and step-bunching, processes in material preparation were elucidated. Some speakers addressed pattern formation due to interplay between surface and transport processes. The variety of structures created by the self-assembly of colloid-size particles was revealed. Particularly intriguing in the poster presentations were the results of Monte Carlo simulations of a two-step phase transition in a 2D metal system.

Symposium Support: Lucent Tech/Bell Labs, NASA, and LLNL.

Complexity of Corrosion and Oxidation Studied

In Symposium S, speakers presented research that effectively spanned the realm of techniques and analysis schemes ranging from atomic-scale modeling and oxide structure determination to the interdependent effects in complex corroding systems. K.R. Zavadil (SNL) presented electrochemical and surface analysis data demonstrating the ability to engineer specific oxide defects (i.e., oxide vacancies) into an aluminum oxide and to determine their impact on electrochemical behavior. The surface studies of S.Y. Yu and P.M. Natishan of the Naval Research Laboratory made arguments for the role of chloride ingress prior to oxide breakdown, and J.R. Scully and R.G. Kelly of the University of Virginia definitively demonstrated how both synergy and competition between neighboring sites comes to bear in complex corroding systems. X. Chen (ANL) introduced fluctuation electron microscopy as a tool to probe degree of order in amor-

No Time Too Short for Materials Interactions

In the new Symposium on femtosecond materials science and technology, Symposium Q, talks ranged from applications of ultrashort laser pulses in materials processing to the fundamentals of the interaction between highly intense laser pulses and materials. On the theoretical side, several presentations aimed to understand the nature of the interaction between femtosecond pulses and materials. While many features of this interaction are well understood, many open questions remain, especially in the regime of extremely intense fields. On the applied side, several groups reported on micromachining of materials using femtosecond laser pulses. Femtosecond lasers allow very precise surface and bulk micromachining with minimal collateral damage to material around the irradiated region. Experiments were reported in a wide variety of materials, from soft organic polymers to diamond to stainless steel. In bulk transparent materials, femtosecond lasers have been used to directly write optical waveguides opening the door to 3D telecommunications devices (see Figure). In addition, several exciting novel techniques were reported, including faster HF etching of laser-irradiated glass, the use of spatially interfering femtosecond pulses for single-shot formation of diffraction gratings, and the use of ultrashort laser pulses in isotope separation, ultrafast phase changes, and the manufacturing of MEMS devices.

Symposium Support: Quantronix and Spectra Physics.

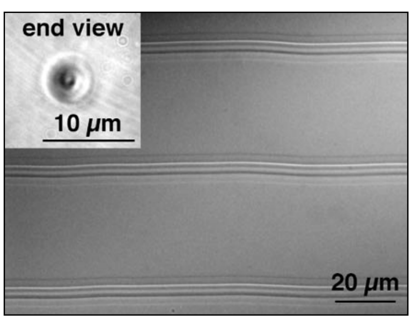

Figure. Optical microscope image of waveguides written in bulk glass using a femtosecond laser.

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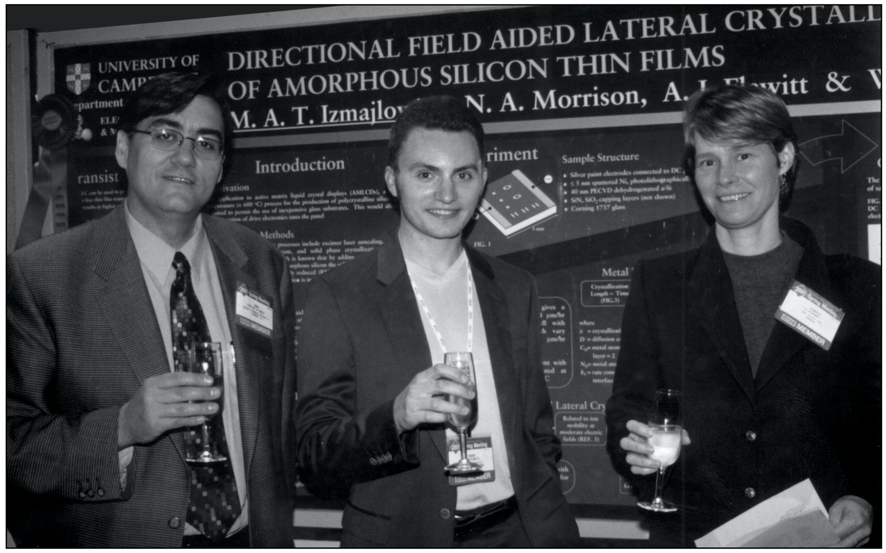
phous alumina and used these measurements to explain the beneficial passivation of aluminum by ozone oxidation.

Symposium Support: AFOSR.

Spintronics Revolution Takes Its Turn
(See MRS Proceedings Volume 674)

Symposium T highlighted the area of spintronics and its applications to recording, sensors, and quantum computing. It covered new materials and structures that use the mechanism of spin-dependent transport, including GMR materials and

Poster Prizes Awarded at the 2001 MRS Spring Meeting



M.A.T. Izmajlowicz of Cambridge University (center) receives a poster prize from 2001 MRS Spring Meeting Chairs Tomás Díaz de la Rubia (LLNL) and Cynthia Volkert (MPI—Stuttgart).

The 2001 MRS Spring Meeting chairs Nicholas Cowern (Philips Research Laboratories), Tomás Díaz de la Rubia (Lawrence Livermore National Laboratory), Chad A. Mirkin (Northwestern University), and Cynthia Volkert (Max-Planck-Institute—Stuttgart) awarded prizes for the best poster presentation. Prize recipients from poster sessions received $500, a certificate, and the honor of having the winning poster displayed for the remainder of the Meeting. Posters awarded prizes and their authors were (A6.7) **Directional Field Aided Lateral Crystallization of Amorphous Silicon Thin Films**, M.A.T. Izmajlowicz, A.J. Flewitt, and W.I. Milne (Cambridge University); (A22.4) **Hydrogented Amorphous Silicon Sub-Band Gap Absorption Measurements Using the Cavity Ring Down Technique**, Arno Smets, Jean-Pierre van Helden, Daan Schram, and Richard van de Sanden (Eindhoven University of Technology); (C5.39) **Fundamental Studies on *n*-Type Polymers and Their Incorporation into Photovoltaic Devices**, Michael F. Durstock, Max D. Alexander Jr., Jeff W. Baur, Thuy D. Dang, and Fred E. Arnold (Air Force Research Laboratory, Wright-Patterson Air Force Base) and Barney E. Taylor (University of Dayton Research Institute); (C8.49) **Chromatic Behavior of Self-Assembled Polydiacetylene/Silica Nanocomposite Films**, Yi Yang, Yunfeng Lu, Mengcheng Lu, Jinman Huang, and Gabriel Lopez (University of New Mexico) and Darryl Y. Sasaki, Alan Burns, and C. Jeffrey Brinker (Sandia National Laboratories); (D5.21) **Numerical Simulation and Analysis of Excimer-Laser Induced Lateral Solidification of Thin Si Films**, Dongbyum Kim, Hans S. Cho, Alexander B. Limanov, and James S. Im (Columbia University) and John P. Leonard (Harvard University); (E9.16) **Aluminum Nitride (AlN) Thin Films for AW Sensors for Biological Detection**, Chantelle Hughes, G.W. Auner, R. Naik, C. Huang, and Gina Shreve (Wayne State University); (L7.11) **Correlations Between Structural Characteristics and Process Conditions of HSQ Based Porous Low-*k* Thin Films**, Hae-Jeong Lee, Eric K. Lin, Howard Wang, and Wen-li Wu (National Institute of Standards and Technology) and Wei Chen and Thomas A. Deis (Dow Corning); (P3.12) **Thickness-Fringe Contrast Analysis of Defects in GaN**, J.K. Farrer and C.B. Carter (University of Minnesota); (V3.2) **Investigations of Sputtered Silver Oxide Deposits for the Super-Rens High Density Optical Data Storage Application**, Dorothea Büchel, Christophe Mihalcea, Toshio Fukaya, Junji Tominaga, and Nobofumi Atoda (National Institute for Advanced Interdisciplinary Research, Japan); (Y8.14) **Thin YSZ Nanolayers Prepared by Chemical Vapor Deposition**, Johannes Seydel, Markus Winterer, and Horst Hahn (University of Technology, Germany); (Y8.32) **Biomedical Application of Ferrofluids Containing Magnetite Nanoparticles**, Do Kyung Kim, Mamoun Muhammed, and Wolfgang Voit (Royal Institute of Technology, Engineering Materials Physics Division and XaarJet AB, Sweden), Werner Zapka (XaarJet AB, Sweden), Borje Bjelke (Karolinska Institute, Sweden), and K.V. Rao (Royal Institute of Technology, Sweden); (AA4.4) **3D Mini-Band Formation and Phase Transitions in a Quantum Dot** Superlattice, Lazarenkova and Alexander A. Balandin (University of California—Riverside); (AA7.10) **Modeling of Sol-Gel Transition with Loop Network Formation and Its Implications on Mechanical Properties**, Hang-Shing Ma, Jean-H. Prévost, and George W. Scherer (Princeton University) and Rémi Jullien (Université Montpellier II, France); (BB3.8) **Stress Patterns of Deformation Induced Planar Dislocation Boundaries**, Hussein M. Zbib (Washington State University) and Darcy A. Hughes (Sandia National Laboratories); (FF4.3) **Investigation of Self-Assembled INP Quantum Islands by Transmission Electron Microscopy**, Angelo Fantini and Fritz Phillipp (Max-Planck-Institut für Metallforschung, Stuttgart) and Joerg Porsche and Ferdinand Scholz (Stuttgart University); (UMRI-6) **Transmission Electron Microscopy of Nanometer Sized Projections Developed During Ion Bombardment: Implications for Depth Profiling Surface Analysis Techniques**, Jack Kollwitz and Kim W. Pierson (University of Wisconsin); (UMRI-21) **Characterization of Chalcocites Produced by Thermal and Plasma Assisted Sulfurization**, Chris Fischer and Colin A. Wolden (Colorado School of Mines); and (UMRI-35) **Improved Efficiency Polymer/Oxide Heterojunction Solar Cells**, Matthew Lloyd and David Braun (California Polytechnic State University).

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MTJs. The Symposium kicked off with J. Daughton's (Nonvolatile Electronics Inc.) tutorial on the "Spintronics Revolution" (pun intended).

One of the key factors that limits the performance of both GMR spin valves and MTJs are pinholes, which are not easily detected. W.F. Egelhoff (NIST) introduced a technique that uses the strong low-temperature dependence of the coupling field on pinholes to separate their effects from effects of magnetostatic coupling, such as the orange-peel effect. Other new directions in materials covered artificial lattices and superlattices, NiO-Co bilayers, and room-temperature spin-flip bilayers of $CoFe_2O_4/\alpha\text{-}Fe_2O_3$.

Taking the field to the "next step,"

Molecular Electronics, Scaling, Biodetection, and Damascus Steel Reviewed in Symposium X

The simplest reason to consider molecules for electronics is that they match the small scale projected in the continuing miniaturization of electronic devices, according to Mark A. Ratner (Northwestern Univ.), one of two speakers on molecular electronics. Ratner said that many molecules are organized on length scales of the order of 60 or 100 nm, which can be used to hold and organize nanoscale particles. However, what makes molecules particularly interesting is that they have recognition capabilities, and thus can self-assemble. "The molecules stick together in a way like controlled Velcro," Ratner said. Different kinds of interactions of molecules aid in self-assembly, such as covalent, ionic, and hydrogen bonding, and hydrophobic interactions.

Ratner said that molecular electronics involves electronic functionality that depends directly upon the molecular organization of matter, which is very different than that of atoms or ions. While molecules do not usually conduct, they can be structured so that charge can be communicated down the line. Mixed molecules "talk" to one another; they interact by weak exchange forces. The best molecules for conduction are covalent structures with strong intrinsic tunneling and weak local repulsion. Good conductive polymeric materials are built on bases like phenylenes and thiophenes, which are big enough that the repulsion is reduced. Ratner concluded by citing three lessons to be learned about building molecular circuits. (1) Efficient junctions are needed for the voltage drop to avoid burning the molecules from the start. (2) Junctions need to be controllable. (3) Molecular electronics goes beyond data processing and storage. Because of their recognition and other functional capabilities, they can be used for sensors, optical protectors, LEDs, assembly-techniques materials, and nanopower sources.

R. Stanley Williams presented the clear rationale for the optimism regarding molecular electronics. Beginning with a historical background on the development of silicon electronics, he compared the ENIAC, the first computer, with current systems. He then asked how much better a computer could be. The answer, he asserted, was suggested by Richard Feynman several decades ago in his book *Feynman Lectures on Computation*. Feynman had asserted that computers can go up to 10^{18} operations/s, which translates to the power of 10^9 current Pentium processors. Williams asserted that for several physics- and engineering-related reasons, this would be difficult to achieve in Si-based systems. Williams quoted Moore's law and then suggested that Moore's second law is also important, that is, the cost of fab increases exponentially with time. Just based on this, continuing with Si does not appear to be feasible.

Williams suggested that two challenges exist for future computing systems: invention of a new switching system and the development of new fabrication processes. He said that the system architecture should be examined first, and the design will need to be scalable for the next 50 years. At Hewlett-Packard he discovered that the architecture for molecular electronics existed, in a system known as the Teramac, in the form of crossbars. The intersection of the crossbars act as switches. Williams' group has explored several molecules and has found that a number of them switch in the crossbar architecture. This architecture is highly fault-tolerant since defective switches can be effectively bypassed. Williams explained some of these systems including $ErSi_2$ with different levels of parallel quantum wires on a Si surface acting as the crossbars. Williams suggested that these systems are very promising and it is just a matter of time before specific devices will be available.

Paul Packan (Intel) spoke on Scaling Transistors into the Next Decade—Challenges in Materials Science. Microprocessor speeds have roughly followed Moore's law doubling in speed every 18 months or so. Are we coming to a slowdown in this development or will Moore's law continue to hold sway for some more time, was one of the questions Packan attempted to answer in his presentation. He ran through the relevant issues including architectures, interconnects, scaling, and high-κ materials. He concluded that new materials will drive and are necessary for the continuance of Moore's law. Fundamental materials research will be crucial for the further development of microprocessors. He also reiterated that these are exciting times for the field. Most developments thus far have been engineering-driven but in the present and in future, developments will be driven more by science.

In the area of biodetection, David Walt (Tufts Univ.) said that the ability to detect biological species is crucial from a health, environment, and safety viewpoint. He described materials aspects of sensors that could be used for this purpose. For an ideal detection system, Walt described a number of approaches, including arrays of sensors and probes. He showed examples of the use of self-amplifying conjugated polymers as ultrasensitive sensors for TNT (land mines detection), luminescent quantum dots (ZnS-capped CdSe), and submicrometer fiber-optic chemical sensors. Walt also described the possible use of nanomaterials for biodetection applications.

Jeffrey Wadsworth (LLNL) discussed the ancient use of laminated composites in order to assist researchers now in their quest to improve superplasticity in steel. The investigation of historical artifacts has also re-opened a debate as to when the iron age began. Wadsworth started with a discussion about Damascus Steel. This material has seen a lot of investigation to determine the cause of its superior properties, and to study the fascinating trademark pattern on its surface. Wadsworth then discussed lamination of steel, including the layering of mild steel on hard steel to blunt crack growth. He gave historical evidence for the lamination of steels such as the Achilles shield and a plate found in the Giza pyramid in Egypt which has been the subject of a lot of speculation regarding its origin and age. Wadsworth said that in Tutankhamen's tomb in the Giza pyramid, a laminated steel plate was discovered. If this is indeed from the time when the pyramid was built, then the iron age would need to be moved from 1000 B.C. to 2500 B.C.

C. Ross (MIT) moved the discussion from micromagnetics to nanomagnetics as she discussed nanopatterned elements made using a unique combination of interference lithography and ion milling. D. Dahlberg (Univ. of Minnesota) gave attendees a magnetic force microscope (MFM) to take home and then described his group's ability to resolve record domain patterns within nanostructures. They can also build nanoships in a bottle using e-beam processes. Cutting-edge magnetic observations were made in mesoscopic ring magnets, trilayers, arrays, and promising high-frequency materials. Participants presented atomic and nanoengineered ferrites (V. Harris of NRL), along with CMR materials.

The device session was opened by E. Yablonovitch (UCLA) who spoke on the benefits of spin for quantum computing using spin resonance transistors. E. Fullerton (IBM) introduced thermally stable high-density recording that uses an antiferromagnetically coupled magnetic media layer. A majority of the talks addressed MTJs, which are magnetic layers separated by an insulating tunnel barrier. This barrier is a benefit, but it also has many challenges associated with it since it is typically made of very thin (1.5 nm), amorphous aluminum oxide. These challenges include feasibility of large-area homogeneity, pinholes, and interruption of metal alloy growth. Several fabrication techniques were introduced, such as AFM nano-oxidation and nonaqueous electrochemistry.

R. Victora (Univ. of Minnesota) and several speakers from the Naval Research Laboratory discussed the elusive topic of spins in semiconductors. The material needed to inject the spin into the semiconductor led to a debate on magnetic semiconductors versus Heusler alloys, each with its own shortcomings. Of particular note was the realization of a spin-LED by B. Jonker (NRL), which used a magnetic semiconductor for the injector.

Symposium Support: ONR/DARPA and ARO.

Meeting attendees discuss resources at the Equipment Exhibit.

Role of Disorder in Ferromagnetic Materials Unraveled

(See MRS Proceedings Volume 674)

Symposium U focused on both fundamental principles and applications of new ferromagnetic materials. The role of disorder in nanostructured materials was a recurrent theme. Structural disorder in a variety of nanocrystalline materials (e.g., compacted clusters of elemental ferromagnets, mechanically milled GdAl and SmCo alloys, and recrystallized melt-spun ribbons) was related to the magnetic properties. J. Löffler (Caltech) described how the magnetic correlation length was determined experimentally for nanocrystalline iron using small-angle neutron scattering.

The degree of order within ferromagnetic materials was also related to magnetic properties. Here the order could be chemical, as in the cell structure phases of Sm_2Co_{17} alloys for permanent magnets, or charge ordering, as in CMR compounds. A number of speakers discussed structural ordering in self-assembled materials made from either micron-sized or nanoscale particles, which could be structured with or without magnetic fields.

The third major theme was the optimization of magnetic materials for various applications through control of composition and processing. These materials included FeCo composites with improved mechanical properties for high temperature, magnetostrictive materials (NiMnGa and TbFe alloys) for actuators and sensors, and nanocrystalline wires for possible nanomotor applications.

Symposium Support: Magnequench Intl.

The Race is on for 100-GB CD-Size Removable Disks

(See MRS Proceedings Volume 674)

CD and DVD technologies are pervasive throughout society and they are one of the success stories involving optical materials and devices. Technology roadmaps for the second half of this decade predict storage capacities exceeding 100 GB for CD-size removable disks, using blue lasers and optics with high light-collection efficiency. Larger storage capacities require commensurately faster data recording and readout rates.

Presentations in Symposium V highlighted different pathways by which these future product goals might be achieved. Magneto-optic recording technology will incorporate ingenious apertures that open and close, and amplify signals under light illumination providing small windows through which data can be recorded and readout at rates exceeding 200 Mbit/s with recording densities over 110 GB/disk. The competitive phase-change recording technology is predicted to have transfer rates approaching 120 Mbit/s with similar capacities. Both technologies have their fiercely competitive proponents and even within the broad class of recording media, competing optical and materials approaches will provide the consumer with an array of options and acronyms to store movies and high-density television multimedia information.

On the scientific front, progress was reported on understanding the materials physics at the nanoscale level, based both on extensive modeling and experimental data. Preliminary results on phase-change media responding to femtosecond pulses were reported as well as detailed data on the relationship between optical recording properties and materials parameters. And if 100 GB/disk is not sufficient capacity, volumetric storage techniques based on holography and multilayer phase-change media promise additional capacity approaching TB/disk before the end of this decade.

Symposium Support: Steag Eta Optik, Philips Research, and Unaxis Balzers AG.

Chemical Ingenuity and Originality Brought to Self-Assembly of Nanomaterials

(See MRS Proceedings Volume 676)

Symposium Y focused on the synthesis, characterization, and applications of nanomaterials. A common theme throughout the Symposium was on the formation of nanostructured materials through self-assembly. Many researchers are using well-defined chemical patterning at the nanoscale to provide both a chemical and a physical template for the self-assembly process in order to control the spatial distribution and orientation of the final molecular assemblies. Soft lithography through the use of AFM is widely used as a chemical patterning tool on various surfaces such as gold, silver, and silicone, to create specifically confined sites onto which carefully chosen molecules can assemble to form a distinct pattern. Reports on the syntheses of various self-assembling molecules were special highlights with their chemical ingenuity and originality; they broadened the scope of nanostructured materials from quantum dots to biosensors. A wide range of novel magnetic, electronic, optical, and catalytic properties and applications, which are unique due to the nanoscale regime, were reported.

Symposium Support: ARO.

Advances in Materials Theory and Modeling Bridge Multiple Length and Time Scales

(See MRS Proceedings Volume 677)

Symposium AA focused on computer simulations of materials, a field which is rapidly moving from the level of fundamental studies into the domain of industrial research and development tools. It was preceded by a Tutorial on "Fundamental Methods of Multiple Length Scale Modeling" and it was concluded by a roundtable discussion about open problems on multiscale materials modeling. A number of speakers discussed the use of computational methods to detect rare events (such as chemical reactions or defect clustering) in the full configurational space. This involves the estimation of paths for going around or across energy barriers. Also, for exponentially complex minimization problems, no consensus emerged for a globally valid method though several methods were clearly suited for specific situations.

The problem of bridging the length-scale gap in mechanical properties was a much debated issue. The importance of defining appropriate boundary conditions for atomistic simulations was emphasized. The current status of using explicit methods, typically based on finite element analysis, to link atomistic and continuum models was also discussed in several talks.

Electronic personal schedulers set up at the 2001 MRS Spring Meeting provided an easy way for attendees to draft their itineraries.

The Symposium provided a thorough review on the recent advances in materials theory and modeling, including several hot topics such as *ab initio* and semi-empirical approaches to electronic and optical properties of materials; simulation of surface reactivity; fundamental aspects of mechanical properties and models of microstructure evolution; and computational methods and algorithms for multiscale modeling and extended-time simulations.

Symposium Support: Istituto Nazionale per la Fisica della Materia (INFM)—Project "MUSIC," and LLNL.

Instabilities Studied from Atomic to Continuum Perspectives

(See MRS Proceedings Volume 683E)

Symposium BB addressed the problem of deformation in metals and related localization phenomena as observed from different length scales, atomic to continuum, and as it applies to small-scale structures such as thin films and nanostructured materials. The speakers presented new experimental techniques and findings pertaining to the characterization of deformation and internal structures, such as dislocations and point defects, as well as to understanding the origin of dislocation and deformation patterns, localization in irradiated materials, and adiabatic shear banding. In the area of modeling of deformation, presentations focused on recent advances that involve new approaches including large-scale 3D atomistic, Monte Carlo, dislocation dynamics, and mesoscopic computer simulations; a variety of new experimental techniques; and the application of several modern statistical physics and strain-gradient theories.

Nuclear Waste Management Focuses on Containment

Symposium CC on the Scientific Basis for Nuclear Waste Management has been a mainstay of the MRS Fall Meeting for a very long time. At the MRS Spring Meeting, a smaller and more focused Symposium was organized on containment materials as a specific nuclear waste materials topic. This Symposium was comprised of two sessions: one on corrosion and chemical issues in evaluating containment materials, and the second on the physical and process aspects of fabricating the materials. The morning session began with presentations on natural analogues demonstrating the long-term stability of certain metallic materials in particular types of environments. Several papers were presented on the corrosion behavior of a range of materials, which are currently under consideration in the different geological repository programs. These included papers on general corrosion under passive conditions, localized corrosion, microbiologically influenced corrosion, and stress-corrosion cracking. In the afternoon session, presentations covered the physical structures of the candidate materials, phase stability, grain-boundary segregation, creep, mechanical properties, and the effect of welding processes on materials performance. Papers dealt with spent fuel cladding and backfill materials in addition to waste package containers and overpack.

Synchroton Radiation Finds Applications from Magnetic Materials to Aging Highways

(See MRS Proceedings Volume 678)

Symposium EE addressed a wide array of topics concerning the use of synchrotron radiation in materials science. Topics included x-ray-diffraction studies of stress and strain, microtomography and microdiffraction for spatial imaging, x-ray fluorescence and microscopy, x-ray absorption spectroscopy and x-ray photoemission studies on magnetic materials, and x-ray scattering at interfaces. The increased use of microbeam diffraction continued a trend established at the 1999 MRS Fall Meeting. There was also a strong emphasis on imaging and texture analysis using diffraction-based methods, particularly to study phase evolution. An afternoon session was devoted to research on the structure of cementitious materials, with a specific focus on corrosion and aging properties of highway structures.

As third-generation synchrotron facilities have come on-line, these high brilliance sources are providing opportunities for characterization with unprecedented atomic-level sensitivity and specificity and for sophisticated probes of electronic properties and 3D structure.

Symposium Support: Blake Industries and Roper Scientific.

TEM Corrector Optics Yields Sub-Å Resolution

Topics presented in Symposium FF represented two related thrusts for materials problem solving with the electron microscope: advanced instrumentation and advanced methodology. One of the most exciting recent developments is the use of corrector optics to yield direct, subangstrom resolution in the next generation of transmission electron microscopes. Correctors are being designed for both probe forming and imaging optics. Both systems have their strengths, and it is likely that commercial instruments will have corrected optics for both applications in addition to advanced monochromators and energy filters/spectrometers. The study of interfaces and disordered materials would clearly be advanced by these subangstrom microscopes. E. Bauer (Arizona State Univ.) provided an overview of the opposite extreme—microscopy with slow electrons—which combines fast data acquisition rates with high topographic and spectroscopic resolution.

Several recent developments in electron diffraction techniques were presented with the unifying theme of using the strong interaction of electrons with matter to provide *quantitative* data inaccessible by other means. These developments include revealing the structure of disordered materials (D.J.H. Cockayne of Oxford and P.M. Voyles of Lucent Tech/Bell Labs), charge distribution and lattice displacement interfaces (Y. Zhu of BNL), and the measurement of bonding charge and *d*-state holes in cuprites (J.M. Zuo of Univ. of Illinois at Urbana-Champaign). J. Spence (Arizona State Univ.) presented recent developments in the ALCHEMI technique that can reveal the position of foreign atoms in a crystal and/or the modification of the lattice by the foreign atom.

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