his personal research has been in this field. From 1965 to 1981 he held the first chair in Britain, at Sussex University, designated in materials science and there he helped to define the nature of the nascent discipline, in part by becoming founder-editor in 1966 of a new periodical, Journal of Materials Science. *Before that, he was founder-editor of the* Journal of Nuclear Materials; *later, in 1985–1992, he helped develop MRS's* Journal of Materials Research, *and since 1993 he has been co-editor of a new journal,* Intermetallics. *He is now attached, in nominal retirement, to his alma mater, Cambridge. Since 1967, he has written approximately 100 articles of scientific popularization in materials science for the weekly journal* Nature. *He was joint editor-in-chief of a series of 18 multi-author volumes (1991–1999) encompassing most of materials science and technology, and has been editorially involved with three materials encyclopedias, one of these now in preparation. He has been editor of two successive monograph series in materials science, first for Cambridge University Press and now for Elsevier Science Ltd. Cahn is currently writing a historical book,* The Coming of Materials Science, *which will appear next year in the Pergamon Materials Series, published by Elsevier. Cahn is a Fellow of the Royal Society of London.*

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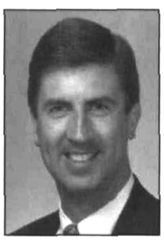

Bravman to Lead Undergraduate Education at Stanford University

John C. Bravman, the chair of the Department of Materials Science and Engineering and the Bing Centennial Professor at Stanford University and 1994 president of the Materials Research Society, has been named vice provost for undergraduate education. Bravman's appointment became effective September 1.

"I'm thrilled and honored to take on the important task of ensuring that Stanford's unparalleled efforts at the undergraduate level continue to move forward," Bravman said.

Provost John Hennessy said that Bravman "brings a real wealth of experience as well as a passion for working for students that I think is truly extraordinary."

While the Stanford Introductory Studies (SIS) developed during the term of the previous vice provost has concentrated on the first two years of the undergraduate experience, Bravman will look toward enhancing the major programs as well as making possible changes in the Science, Mathematics, and Engineering Core, which is an option for nonscience majors in fulfilling the undergraduate general education requirements.

Bravman also will be involved with developing a solid financial basis to sustain the recent improvements in undergraduate offerings at Stanford. He especially will be seeking funds to endow undergraduate research initiatives. "I think perhaps as many as a third of undergraduates are looking for a substantial research experience either over the summer or during the year or both," he said.

Bravman, who will serve a five-year term, will continue as senior associate dean for student affairs in the School of Engineering. He will also continue to conduct research with his group of PhD students. His research focuses on the mechanical behavior of thin film materials and the reliability of the microscopic structures found in computer chips and other microelectronic circuitry. His group has pioneered techniques for imaging and tracking the movements of the microscopic voids that appear in the metal contact lines used in such circuits. The group also is developing methods to test and analyze the fatigue and fractures that develop in thin films. Such methods are needed to identify highly reliable films that can be used in the construction of devices that combine microscopic electronic circuitry and microscopic mechanical components.

After receiving his BS, MS, and PhD degrees in materials science and engineering at Stanford, Bravman was named assistant professor in the department in 1985, achieving full professorship in 1995.

Among other honors, he received the Walter J. Gores Award for Excellence in Teaching in 1989. He also has served as a resident fellow and on a wide variety of committees and boards, including the Commission on Undergraduate Education.

Copper-Indium-Gallium-Diselenide Semiconductor Heals Itself

An international team consisting of David Cahen of the Weizmann Institute's Materials and Interfaces Department, working with consultant Leeor Kronik of Tel Aviv University and colleagues from France's CNRS and Germany's Stuttgart University have discovered a self-healing process that can occur in a copper-indium-gallium-diselenide semiconductor. This finding, presented in June at the European Materials Research Conference in Strasbourg and scheduled for publication in *Advanced Materials*, may help create better solar cells and other electronic devices.

Their discovery is based, among other things, on a study in which crystals of a related material, copper indium diselenide, were examined using high-energy x-rays. In that study, conducted by Cahen and other colleagues at the European Synchrotron Research Facility in Grenoble, it was shown that in some cases the bonds between certain atoms of copper indium diselenide can be broken relatively easily.

Cahen's group had also shown that copper atoms can move inside these semiconductor crystals. He said that this finding was surprising because such movement is uncommon in solid, nonliving materials, and extremely unusual in materials used in electronic devices where atomic mobility is viewed as anathema. Moreover, he said, seeing it in a semiconductor known for its stability was particularly unexpected.

The researchers furthermore found that once some atomic bonds have been broken, the copper atoms, which are capable of moving throughout the crystal, wander around until they reach the damaged spot and undo the effects of the damage. This "self-repair" mechanism stems from the material's tendency to try and stay close to equilibrium.

Cahen said, "Now we understand how solar cells made of copper indium gallium diselenide manage to survive and function effectively in hostile environments such as those encountered on satellites: Once damaged, for example by radiation, this 'smart' material simply 'heals' itself and restores its previous function."

Microwave-Sintered Metal Parts Demonstrate Finer Grain Size than Conventional Sintering

A team of materials scientists at The Pennsylvania State University is microwaving a wide range of powder metals and producing machine components with improved properties over those produced through traditional sintering methods.

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"Solid metals cause problems in microwaves because they reflect, rather than absorb, the microwave radiation," said Dinesh K. Agrawal, professor of materials, senior scientist, and director of Penn State's Microwave Processing and Engineering Center. "Powder metals do absorb microwave radiation and can be heated and sintered, using microwaves."

The key to microwave sintering of powder metals is specialized insulated sintering chambers, as reported in the June 17 issue of *Nature*. In conventional thermal sintering, the sintering oven is heated and this heat is transferred to the greenware, but microwaving does not heat the chamber, just the greenware. Without insulation, the heat generated in the greenware would be lost to the inside of the microwave cavity and it would take a large span of time to reach the required temperatures. The insulated chambers trap the heat and allow temperatures to rise rapidly.

The researchers can also alter the atmosphere of the chamber to include inert noble gases like argon or neon, hydrogen, nitrogen, or forming gas—5% hydrogen and 95% nitrogen.

Agrawal said, "We obtained essentially fully dense bodies with substantially improved mechanical properties compared with identical bodies sintered in the conventional manner." The researchers found a homogeneous microstructure with very little porosity in the microwave-sintered products.

The researchers found that microwave sintering produces a finer grain size than conventional sintering and the shape of any porosities that do exist differs from the conventional product. The microwave-produced porosities led to higher ductility and toughness.

"Our findings indicate that virtually any powder-metal green body can be sintered in 10 to 30 minutes in an appropriate microwave-sintering apparatus," the researchers reported.

The researchers used commercial powder-metal components of various compositions. Metals included iron, steel, copper, aluminum, nickel, molybdenum, cobalt, tungsten, tungsten carbide, and tin. The components included small gears, rings, and tubes.

Migration of Oxygen Vacancies in PZT Film Opens Potential for Application as Oxygen Sensor

While analyzing the effects of temperature change on ferroelectric thin films, scientists at Purdue University discovered that the material is sensitive to oxygen. They found that reducing the atmospheric pressure also reduced the performance of the devices. Further tests showed that the effect was caused specifically by changes in oxygen concentration and in the partial pressure of oxygen in the vacuum chamber.

According to their article published in the June 28 issue of *Applied Physics Letters*, the scientists studied two types of $Pb(Zr,Ti)O_3$ (PZT) films: one in which the Zr/Ti ratio is 55/45, and another that has a 75/25 ratio. Using pulsed laser ablation, the scientists deposited each type of PZT thin film (0.3 μm thick) on Pt-Ti-SiO_2-Si substrates held at 600°C in 300 mTorr of O_2. The scientists then performed fatigue measurements at room temperature.

The oxygen partial pressure, p_{O_2}, of the atmosphere over the sample varied from p_{O_2} ~ 1 atm to 10^{-4} atm which translates as Log[p_{O_2}/atm] ~0 to ~4. At Log[p_{O_2}/atm] ~0, the switchable polarization underwent a rapid decay beginning at approximately 10^5 switching cycles. The number of switching cycles increased monotonically as the oxygen concentration was reduced when testing the PZT-55/45 film. However, as the oxygen concentration was further reduced (to Log[p_{O_2}/atm] ~-0.69), the number of cycles at which fatigue occurred decreased monotonically. For the PZT-75/25 sample, the scientists report a peak at Log[p_{O_2}/atm] ~ -1.3.

The researchers said, "These observations lend support to one prominent theory for ferroelectric fatigue which involves the migration of oxygen vacancies under the influence of the voltage cycling."

With this discovery, the scientists theorized that the material might be useful as an oxygen sensor. Materials now used in conventional solid-state sensors must be heated to at least 300°C. But the material used in the research seems to perform well at room temperature, and it continues to function at temperatures as cold as -93°C, making it suitable for environmental and biological applications.

Calculations Suggest Noncollinear Spin Ordering as Origin of Invar Effect in Iron-Nickel Alloy

In order to explain minimal thermal expansion identified as the Invar effect in an alloy consisting of 35% Ni and 65% Fe, researchers at Sandia National Laboratories and Uppsala University, Sweden performed *ab initio* calculations of the volume dependences of magnetic and thermodynamic properties for the face-centered cubic (fcc) alloy. As reported in the July 1 issue of *Nature*, disordered magnetic spin configurations account for the behavior.

Calculating ground-state spin configurations at various atomic volumes, the researchers found a large contrast in spin orientation as they checked the volumes at 78.8 a.u., 73.7 a.u., 71.9 a.u., and 68.6 a.u. Their model of the alloy contained 21 Fe atoms and 11 Ni atoms. They calculated the electronic structure in the framework of the local spin-density approximation employing the scalar-relativistic linear muffin-tin orbitals (LMTO) method. The researchers said that calculations were performed with 27 *k*-points in the Brillouin zone. They found the ferrimagnetic state at the high volume of 78.8 a.u. as expected, which transformed to an increasingly disordered noncollinear state as the volume decreased.

The researchers furthermore studied spin-pair correlation functions between neighboring spins at several atomic volumes. According to their report, "There is a transition from a nearly ferromagnetic ordering...in Fe-Fe nearest-neighbor (NN) spins at large volume, to an approximately uniform distribution of spins for small volumes. In contrast, the NN Ni-Ni spins remain nearly ferromagnetically aligned along the magnetization direction at all volumes."

The researchers said that the difference between the high-volume state (HS) and the noncollinear equilibrium volumes is ~1% which agrees with previously reported experimental results of 0.5–2%, demonstrating that the equilibrium volume for the noncollinear alloy is situated between the ferromagnetic HS and paramagnetic states. They also suggest that the stability of the nonzero transverse component in the magnetic ground state of the alloy ($T = 0$ K) accounts for the "anomalies" in the temperature-dependence of the magnetic moments in these Invar systems.

Replication Process Mass Produces High-Quality Telescopic Mirrors

X-ray astronomer Brian Ramsey and colleagues working in the Science Directorate at NASA's Marshall Space Flight Center, together with Darell Engelhaupt of the University of Alabama—Huntsville, have utilized a replication method for manufacturing multiple high-quality copies of a mirror for the High-Energy Replicated Optics (HERO) telescope.

"In these mirrors, we're using two straight cones instead of curved surfaces," Ramsey said. "This means the mirrors will provide images that are just a little out of focus, but it doesn't matter. The effect is very tiny, much smaller than the average resolution we expect to achieve. The departure is insignificant to the imaging properties." Ramsey said that their replication method also simplifies manufacturing.

The scientists start with an aluminum mandrel that is machined into part of a double shallow cone called frustra. It is coated with nickel and superpolished to a roughness of <0.5 nm. Raytheon optical engineer Chet Speegle has refined the polishing process from three months to one month for a mandrel.

The mandrel is then immersed in a chemical bath to electroplate it with a shell of a proprietary nickel alloy to a thickness of about 0.25 mm. Ramsey said, "The shell material behaves more like a ceramic than a metal. It's brittle and will not bend. That's ideal for a mirror because it means it does not permanently deform it as pure nickel would. We developed this material to satisfy future needs for large-area, high-resolution x-ray optics."

The scientists said that electroforming currently takes about three days, which

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they expect to shorten as they improve the process. They also said that several mandrels can be electroplated at a time, completing a set of nested mirrors out of the same bath.

The mandrel is cooled so it contracts and the electroplated shell pulls away, forming the new mirror. The scientists said that conventional electroformed pure-nickel mirrors would not survive this process without deforming. The HERO mirror is then vacuum coated with iridium, a hard reflective metal, and is ready for assembly into a nested array to make a telescope.

Ramsey said, "We got 33 arc-seconds resolution, a result we were very pleased with." The team continues its work to improve the resolution.

Molecules in 14-nm Polymer Films Retain Shape and Size of Those in Bulk Form

In a search to find at what dimensions ultrathin polymer films will no longer behave the same as bulk polymers, researchers at The Pennsylvania State University have come closer to understanding why the molecules behave the same as in bulk form. Ronald L. Jones, a graduate student in polymer science, said, "We are trying to see if the molecules of polymers in ultrathin films of only 14 nm had the same shape and size as the molecules in the bulk material."

According to their report published in the July 8 issue of *Nature*, the researchers used polystyrene to create ultrathin films on small silicon disks. They chose silicon because its surface can be polished to an almost molecularly smooth finish and it is transparent to a neutron beam. The researchers used a small-angle neutron scattering device to determine the size and shape of the molecules.

Sanat K. Kumar, professor of materials science and engineering, said that the shape of the molecule changed very little from the spherical shape of the molecule in bulk form.

While the 14 nm thin film is much thicker than a single atom, the diameter of the polymer ball in the bulk material is larger than the film's thickness. The researchers believe that the polymer spheres have a lot of space inside so that while the basic shape remains the same, the packing of the molecules inside the ball is more efficient.

Jones said that the molecules in the thin film may be less tangled than in the bulk polymer, but the researchers have not yet tested this.

"We know that the bulk material is organized in a very random way," said Kumar. "We can measure the randomness of the molecular organization in the 14 nm thin film and we know that they are still random. These thin films are not ordered."

APS Awards Feldman, Anthony, Haller, DMP Names 10 Fellows

During the American Physical Society Centennial Meeting held in March in Atlanta, **Leonard C. Feldman** of Vanderbilt University and a member of the Materials Research Society (MRS) received the 1999

SBIR Update

PIEZOMAX Technologies, Inc., (Madison, Wisconsin) has recently been awarded two Phase I and one Phase II Small Business Innovation Research (SBIR) contracts from the Department of Defense, totaling more than $900,000, for development of piezo-actuated high-speed precision motion stages, probe and sensor development, and materials evaluation, all focused toward high-speed surface metrology and lithography.

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David Adler Lectureship Award "for distinguished research and lecturing on ion beam analysis, semiconductor surfaces and thin film growth." The award recognizes outstanding contributors to the field of materials physics who are noted for the quality of their research, review articles, and lecturing. The lectureship was originally endowed in 1988 by contributions from friends of the late David Adler of the Massachusetts Institute of Technology.

MRS members **Thomas R. Anthony** of General Electric Research and Development Center and **Eugene E. Haller** of the University of California—Berkeley received the McGroddy Prize "for innovations in growing diamond and germanium crystals with unprecedented control of chemical and isotopic purity and perfection, and for creative leadership and active participation in worldwide collaborations based on these extraordinary materials resulting in both fundamental discoveries and new technological applications." The James C. McGroddy Prize recognizes and encourages outstanding achievement in the science and application of new materials, including the discovery of new classes of materials, the observation of novel phenomena in known materials leading to both fundamentally new applications and scientific insights, and theoretical and experimental work contributing significantly to the understanding of such phenomena.

Five members of MRS honored as new APS Fellows sponsored by the Division of Materials Physics (DMP) are **Ivan Bozovic** of Varian Research Center for his outstanding contributions to atomic-layer engineering of cuprate superconductors and other complex oxides, fabrication of delicate multilayers and superlattices, and their innovative spectroscopic characterization; **Roberto Car** of the Universite de Geneve for outstanding contributions to physics, especially the combination of molecular dynamics with density functional theory which has proven to be a powerful method to study atomic-scale dynamics in molecules and solids; **Robin F.C. Farrow** of IBM Almaden Research Center for pioneering the development of molecular-beam epitaxy to grow and study epitaxial semiconductors, metastable phases, dielectrics, magnetic elements, and alloys; **Arunava Gupta** of IBM T.J. Watson Research Center for contributions to the development of pulsed laser deposition techniques, the use of this technique for the production of materials with novel physical properties, and for original contributions to the understanding of nonequilibrium film-growth mechanisms; and **Matthias Scheffler** of Max-Planck-Gesellschaft for significant contributions to elucidating atomic-scale structures in solids and solid surfaces by first-principles approaches. DMP also sponsored as APS Fellows **Joseph E. Greene** of the University of Illinois for original contributions to the experimental development, modeling, and understanding of Si, Ge, and $Si_{1-x}Ge_x$ atomic-layer epitaxy and gas-source molecular-beam epitaxy; **Francoise K. LeGoues** of IBM T. J. Watson Research Center for insightful contributions and creative use of electron microscopy in determining mechanisms of strain relaxation in heteroepitaxial growth of semiconductor thin films; **Brian Craig Sales** of Oak Ridge National Laboratory for development of important new materials for the storage of nuclear waste and for the generation of electrical power; **Peter Wesley Stephens** of the State University of New York-Stony Brook for determination of the structure of fullerene materials and elucidation of the relationships between their structures and physical properties; and **Zhenyu Zhang** of Oak Ridge National Laboratory for original and innovative contributions to the understanding of thin-film growth mechanisms and kinetic/dynamical processes at surfaces.

See the MRS Website for Materials News

www.mrs.org/matl_news.html

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Lockwood Elected as Fellow of the Royal Society of Canada

David J. Lockwood of the Institute for Microstructural Sciences at the National Research Council of Canada was elected as a Fellow of the Royal Society of Canada, the highest distinction accorded scientists in Canada. He was cited for "his outstanding work on optical emission due to quantum confinement in semiconductor nanostructures and his use of inelastic light scattering to elucidate the dynamical properties of superlattices, magnets, and phase transitions."

Lockwood completed his PhD studies in solid-state physics at the University of Canterbury, New Zealand in 1969 and was awarded a DSc degree in physics by Edinburgh University, Scotland in 1978. He worked as a postdoctoral fellow at the University of Waterloo, Canada and as a research fellow at Edinburgh University before joining the National Research Council of Canada in 1978, where he is now a principal research officer.

Lockwood is also a member of the Materials Research Society, the Electrochemical Society, and the Canadian Association of Physicists, and was elected Fellow of the American Physical Society in 1997. He serves on the editorial boards of *Solid State Communications*, *Physica E*, and *Physics in Canada*, has served on NATO Science and NSERC (Canada) advisory committees, and has organized a number of international conferences and workshops in the general area of the optical properties of materials. He has published over 300 papers and 12 books on light emission and light scattering in semiconductors and insulators.

This year's new Fellows will be inducted to the Society at a ceremony to take place in Ottawa on November 19, 1999. □

SEND LETTERS TO THE EDITOR TO:

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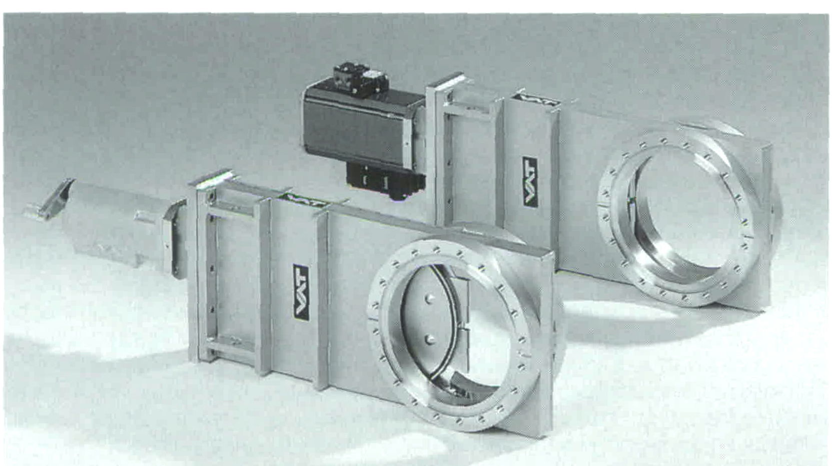

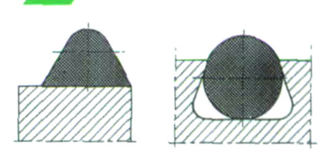

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