Dual Temperature Crystal Orientation of YBCO Large Crystals

The Melt-Powder-Melt-Growth (MPMG) group of ISTEC's Superconducting Research Laboratory (SRL) in Japan has succeeded in controlling the crystal orientation of YBCO large crystals grown by the MPMG method. As a result, the levitation and attractive forces for this superconducting material have been tripled. The SRL MPMG group, headed by Masato Murakami and including Hiroshi Takaichi and Naomichi Sakai, is conducting research aimed at improving the superconducting properties of melt-pressed YBCO.

Since high-temperature superconductors have a very anisotropic crystal structure, it is important to control the crystal orientation of YBCO crystals for any practical applications. Although many research groups had tried to develop techniques to do this, it had become clear that it is quite difficult to perfectly control the crystal orientation by simply using either a temperature gradient or a seeding technique.

The MPMG group has found, however, that the crystal orientation can be controlled by using temperature gradients in two directions; the temperature gradient in one direction should be at least four times larger than the gradient in the other direction (5°C/cm and 20°C/cm).

The group has succeeded in growing a large pellet—8 cm in diameter and 3 cm thick—by extra heating and forced cooling (air and water), by utilizing units installed inside a box furnace. They slowly cooled each sample from the molten state, while maintaining constant temperature gradients. Using this bulk material and a 0.5 T magnet, they recorded a repulsive force of 20 kg at a gap of 0.1 mm. This value is three times larger than that of a YBCO pellet produced by a conventional method.

This success opens up the possibility of producing not only superconductivity bearings and flywheels with high performance, but also electric current leads, magnet shielding rooms, and magnetic clamps. This research will soon be submitted to either the *Japanese Journal of Applied Physics* or J-MRS.

F.S. Myers

Laser Method Produces Improved Carbon Fiber

Frederick T. Wallenberger, a University of Illinois researcher, has developed a way to make strong, chemically pure, and structurally uniform carbon fibers that could improve infrared optical sensors. The process involves the deposition of very pure carbon by heating methane vapor with a laser beam.

The heated vapor breaks down into its components, freeing hydrogen and depositing hot carbon on a steadily moving platform. The motion allows a rodlike fiber to form and lengthen as carbon continues to accumulate at the laser's focal point. The forming carbon fiber is free of the impurities that commonly taint carbon rods derived from roasting pitch or charring fibers. Because the rod forms within a gas, the carbon also is free from contamination by container walls.

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The technique evolved from one used by applied physicists to study the process of deposition. Physicists perform laser-assisted carbon deposition, but at extremely low pressure, a condition that causes carbon to precipitate very slowly.

Wallenberger and collaborator Paul C. Nordine used reactor chamber pressures as high as 15 atmospheres, creating the growth of carbon fibers at rates at least 30 times faster than that previously achieved. According to Wallenberger, the carbon produced could become the substrate of choice in emerging applications such as carbon-fiber infrared sensors. Such sensors must be pure and structurally uniform to record data accurately.

Titanium Oxide Aids in Bonding High Conductivity Metals to Integrated Circuits

Researchers at the Georgia Insitute of Technology report that a thin film of titanium oxide can serve as an intermediary layer to help bond films of high conductivity gold to the other materials used to build an integrated circuit.

Aluminum has long been used for wiring in integrated circuits because it forms a stable insulating oxide to which other electronic materials readily bond. But engineers would like to use higher conductivity metals such as gold, silver, and copper to increase the speed of the circuits and to reduce the current they must carry. Higher conductivity would also mean less current loss and less heat to remove from the circuit module. Many of the metals that are better conductors than aluminum, however, do not readily form stable oxides and are therefore more difficult to use in layering the circuits.

Paul A. Kohl, a professor at Georgia, and Kirkland W. Vogt, a graduate student, believe they have solved that problem by depositing a thin film of titanium metal on top of gold conducting films. The titanium adheres well to the gold, and is then allowed to form an insulating oxide (TiO_2) on which the researchers can build layers of silicon dioxide or polymers.

This one-step coating process allows them to switch back and forth between insulators and metals without having to worry about adhesion for each. Because the titanium film is thin, it does not alter the dielectric properties of the insulator surrounding the metal. And because it does not significantly diffuse into the gold, conductivity is not degraded.

Using angle-resolved x-ray photoelectron spectroscopy and scanning tunneling microscopy, the team studied the characteristics of the titanium oxide film and found that its thickness was critical to the success of the process.

When deposited in layers of between three and 10 angstroms thick on the gold film, the titanium forms "islands" which occupy about 90 percent of the surface, but do not contact one another. Oxidation of the titanium metal creates a continuous film of insulating titanium oxide, which builds up on top of the titanium islands and provides a bonding surface for the next layer of the circuit. A core of titanium metal remains beneath the oxide to provide good adhesion to the gold. The oxidation of thinner layers does not leave enough titanium to ensure good adhesion and, in thicker layers, the titanium islands grow together, potentially causing a short circuit.

Osbourn Wins APS New Materials Prize

Physicist Gordon C. Osbourn of Sandia National Laboratories received the American Physical Society's 1993 International Prize for New Materials.

The award honors his theory and innovations, which already have led to a variety of new semiconductor lasers and transistors and opened up numerous chemical combinations for designing new materials having special electrical and optical properties.

Osbourn made the first theoretical calculations that predicted the unique electrical and optical properties of strained-layer superlattice (SLS) materials. This theory and the subsequent development of the technology have led to the ability to tailor-make a variety of new materials with unique optical and electronic properties.

The biggest impact of SLS principles has been in the use of semiconductor lasers for light-wave communications through optical fibers. Having proved to be more stable and to have lower thresholds, SLS materials are rapidly replacing copper wires for communications. SLS technology is now used in making transistors for high-frequency, low-noise electronic amplifiers. One example is in sensitive amplifiers at the Very Large Array radiotelescope facility near Socorro, New Mexico. A number of specialized military applications also make use of the SLS transistors.

SRC to Update Faculty Directory

The Semiconductor Research Corporation (SRC) is updating its directory of key faculty who are performing semiconductor-related research. This year, the project will be expanded to include all full-time faculty in Canada, and to broaden the coverage in the United States.

From June through September 1993, the SRC and Synergistic Technologies—its partner in the project—are surveying full-time faculty at research institutions by asking those engaged in semiconductor research to complete a one-page questionnaire about their research activities and interests. A broad definition of semiconductor research will include research involving devices, design, process technology, manufacturing systems, packaging, and reliability issues.

The Semiconductor Research Faculty Profile, consisting of both a computer database and a bound directory of U.S. faculty, will be published in January.

Researchers included in the second edition will automatically be mailed a questionnaire for updating. Others may be included in the third edition by completing a questionnaire and forwarding it to the SRC. Questionnaires will be printed in the SRC Newsletter or may be obtained by calling (919) 541-9400.

STM Used for Measuring Microhardness

A new method has been developed by researchers at the National Research Institute for Metals of Japan to measure microhardness using a scanning tunneling microscope (STM). The method, developed by Saburo Matsuoka, Nobuo Nagashima, and Kensuke Miyahara of the Environmental Performance Division, along with Hiroyuki Masuda of the Failure Physics Division, involves contacting the sample surface with an STM tip, thus enabling the observation of both indentations and grooves. In this way, the characteristics of materials having a nanometer-order range of microhardness, impossible to measure with conventional optical microscopes, can be investigated.

One theory concerning the development of intelligent materials entails implanting substances that can be used to generate sound waves when the material is damaged, or to cause a material modification at the locations of defects. The self-diagnosis of damage and deterioration, as well as self-restoration, will then be performed by the materials. Measuring the microhardness should be quite useful for elucidating the interface characteristics of an implanted substance, as well as various intelligent functions of materials.

Generally, microhardness has been measured by forming indentations with a gram-order weight in a hardness tester, then the size of the indent is measured using either an optical or electron microscope to determine the hardness. Finer indents have been made relying on the relationship between load and indentation depth, but with loss of accuracy due to the difficulty of determining the exact tip shape (sharpness).

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In the new measurement system, an STM having an atomic-level resolution produces indentations. Additionally, the tip shape can be examined through the three-dimensional STM image of the indentation. The process involves applying a pulse-form tunnel voltage between the STM tip and the sample. At the instant that the voltage becomes zero, a servo mechanism is turned off as the tip contacts the sample with the piezoelectric element force and produces an indentation. In experiments, spherical cementite steel (JIS (Japan Industrial Standards) 25C) was used along with a special type of tip in which boron was implanted in a diamond and made electroconductive. A tunnel voltage of zero was applied in a pulse form under the following STM measurement conditions: a tunneling voltage of 50–500 mV, a tunneling current of 1 nA, and a zero-voltage retention period of 3–26 ms.

At a 300–1,000 nm pitch, as many as 61 microindentations of 50–200 nm size, arranged in eight rows and eight columns, were produced. Indentations were usually observed in cementite particles as mere points with small undulations; in an iron-based material (ferrite), however, indentations 50 nm wide and deep were clearly visible. As a result, it was possible to compare the hardness of both materials with relative ease.

As semiconductor devices become more highly integrated, this new technique is expected to play a valuable role in elucidating the condition of semiconductor device circuits. To this end, the research group is now developing an ultrahigh vacuum atomic-force microscope to enable an estimation of indentation depths for a more accurate evaluation of microhardness.

F.S. Myers

American Vacuum Society Adds Nanometer Science and Technology Division

The American Vacuum Society has established a new Nanometer Science and Technology Division (NSTD) in an effort to stimulate emerging technologies related to the Society's emphasis on materials science at surfaces/interfaces and on vacuum-related technologies. The objectives of the NSTD are to provide a continuing forum for discussion of nanometer-scale structures; promote continuing development of proximal probes (STM, AFM, etc.); foster technology transfer involving nanometer-scale structures; organize meetings and symposia; publish original works and critical reviews in proceedings, technical journals, and books; work collaboratively with the other AVS divisions; and participate actively in all phases of the AVS programs.

The NSTD will sponsor six sessions of the Society's 40th National Symposium to be held November 15–19 in Orlando, Florida. The session are: Nanotechnology: Sensors, Micro-Machining, Nanometer Modification, Manipulation, and Control; Photo-Based SXM; Innovations in Proximal Probes; Nanomechanics; Ultra Electronics; and Aspects of Nanometer-Scale Science and Technology: Poster Session. The NSTD will also co-sponsor joint sessions with other divisions in the areas of film growth, surface cleaning, sensors, biomaterial interfaces, and manufacturing science. Rich Colton of the Naval Research Laboratory is serving as chair on the Founding Board for the new division.

New NAS Members Elected

The National Academy of Sciences (NAS) elected 60 new members and 15 foreign associates during its 130th annual meeting held in April. The recognition is considered one of the highest honors accorded to a scientist or engineer. The number of active members now totals 1,683, and foreign associates number 298.

Established by an act of Congress, NAS is a private organization of scientists and engineers dedicated to the furtherance of science and its use for the general welfare. NAS acts as an official adviser to the federal government in matters of science and technology.

MRS members newly elected to NAS are:

Malcolm R. Beasley, professor of applied physics and electrical engineering, Stanford University;

Tobin J. Marks, professor of chemistry, Northwestern University; and

Alexandra Navrotsky, professor of geological and geophysical sciences, and Albert G. Blanke Jr. Professor of Geological and Geophysical Sciences, Princeton University.

Process Developed to Monitor Steel Corrosion in Concrete

Because steel-reinforced concrete is particularly efficient at absorbing compressive and tensile forces, it is often used in road bridges, multistory parking garages, and load-bearing walls. However, the steel ribs embedded in the mixture of sand and cement are subject to corrosion when chlorine salts penetrate the pores of the concrete.

Scientists at the Rhenish Westphalian Technical University in Aachen, Germany, have recently developed a process for continuously monitoring and gauging the rate of such steel corrosion. The process is based on the fact that iron ions are dissolved and electrons released at the rust spots on the surface of the steel. These surplus electrons react with oxygen and water on the surrounding steel surfaces. The corrosion rate can then be measured as an electric current flowing between the two adjacent steel surface areas, due to the direct correlation between the dissolving of the iron and the current. Sensors have now been developed which, when embedded into the concrete of new buildings, can permanently monitor and indicate the danger of corrosion. From *Special Science Reports, German Research Service* **IX,** No. 3/93, p. 5.

X-Ray Tomographic Microscopy Reveals 3-D Image of Ceramic Composite Formation

A team of scientists from Lawrence Livermore National Laboratory, Sandia National Laboratory, and the Georgia Institute of Technology are using x-ray tomographic microscopy to visualize the step-by-step formation of a ceramic composite material in three dimensions and in microscopic detail. The x-ray tomographic microscopy method used was developed at Livermore and Sandia over the last four years, partly under the sponsorship of the Strategic Defense Initiative Organization.

The method can detect features as small as 1 micron across, with a resolution of 5 microns. X-ray tomographic microscopy techniques developed at the labs are similar to the CAT scans used in medical diagnostics, but with a millionfold better resolution of volume. They also can collect data for up to 1,000 tomographic slices at a time, compared to one slice at a time for medical and commercial instrumentation. The system then reassembles this data electronically to form a three-dimensional picture of the object's interior. When used to study ceramic-matrix composites during fabrication, the images show researchers how vapor deposition progresses in three dimensions, and allow quantitative measurements.

As reported in the May 7 issue of *Science*, the researchers observed the formation of the ceramic composites, silicon

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carbide/silicon carbide. This is actually a family of materials that are noted for their strength, toughness, and ability to withstand corrosion and high temperatures. However, their properties are hard to control and they are expensive to make.

Fine, amorphous silicon carbide fibers, about 10 microns in diameter, are formed and spun into threads, woven into a cloth and formed into the desired shape. Spaces between threads and in the cloth structure are then filled at high temperature by a gas which deposits crystalline silicon carbide. As much of the void volume as possible must be filled to yield a dense material having the most desirable properties. Because the growth was closely observed at every stage, it was the first time researchers could see how the complex architecture of the material determined its growth and consolidation. This technique suggests how, in the future, the microstructure of certain materials could be controlled, thus tailoring materials to produce good mechanical properties and reduce cost.

Net Form Metal-Working Process Uses Three-Dimensional "Printing" Technique

Melissa Orme, Terence G. Langdon, and E. Phillip Muntz from the University of Southern California are collaborating on a project to invent a "net form" metal-working process that can create completely finished, ready-to-use objects from raw stock. Supported by a $500,000 grant from the National Science Foundation, this project promises to produce computer "printouts" for forming fully molded and finished three-dimensional objects.

Current metal-working processes such as casting, machining, and forging generally require that the part be cleaned, polished, or cut afterward. The USC group has patented a process that uses a nozzle to dispense a precision stream of molten metal droplets, building up the parts, drop by drop, into precisely the shapes desired.

The trick is to lay down the successive layers of metal so that the drops of molten material fuse completely with their still-soft predecessors. If this is done properly (with correct timing and temperature control), the result is metal with a finer grain structure and consequently, greater strength than metals created by conventional methods.

Thus far, the group has used only a low-melting-point material called Rose's metal. The next step is to move to aluminum, which is far more useful, but which has a melting point about 900°F (500°C) higher.

Researchers at the Massachusetts Institute of Technology are using modified heads from ink-jet printers to build up shapes from droplets of wax. The head that Orme designed for her three-dimensional part-making system operates on a different principle. It breaks up a fluid column of molten metal flowing through a vacuum into a stream of extremely uniform droplets, each about .004 inch in diameter, which can be directed with great precision. Orme's calculations and experience indicate that pieces can be constructed to tolerances of approximately .002 of an inch.

The process can be adapted to the fabrication of high-technology metal matrix composite materials either by depositing metal around a skeleton of fiber or by feeding fibers into the piece as it is formed. This technique also permits adjustment of the feed metal mixture, so that different mixtures of alloy can be used in different parts of the same piece to alter strength, flexibility, etc.

According to the researchers, this process has two advantages. First, the part is metallurgically superior due to the rapid solidification techniques. Second, this technique has the economic advantage of making the object in one integrated step.

Roy Awarded Highest Honor by ACerS

Rustum Roy, Evan Pugh Professor of the Solid State, professor of geochemistry, and professor of science, technology, and society at Pennsylvania State University, has received the Distinguished Life Membership Award from the American Ceramic Society. He was recognized for his dedication and service to ceramic science and materials policy as an educator, researcher, author, and humanitarian.

After earning degrees from Patna University, India, Roy received a PhD in ceramics from Penn State in 1948 and

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began his career at the university. The author/co-author of several books and more than 600 papers, Roy has founded and edited numerous journals and newsletters in materials science and engineering education. His research has included hydrothermal processing, sol-gel science, nucleation in glass, radioactive wastes, nanocomposites, superconductors, and phase equilibria of titanate, silicate, and alkali halide systems. In 1973 he was elected to the U.S. National Academy of Engineering, and in 1991 was elected to the Engineering Academy of Japan.

Researchers to be Honored for Blue/Green Diode Laser

Robert M. Park of the University of Florida’s Department of Materials Science and Engineering and Hwa Cheng, James M. DePuydt, Michael A. Haase, and Jean Qiu of the 3M Company’s Corporate Research and Development Laboratories are to receive the 1993 Rank Prize for Optoelectronics. The prize, to be awarded in London on November 30, is in recognition of the researchers’ collaborative work on the doping technique which allowed p-type ZnSe to be grown successfully, and their subsequent demonstration of laser action in the blue/green spectral region using laser diodes fabricated from ZnSe-based materials.

Matijevic First Recipient of Iler Award

Clarkson University’s Egon Matijevic, Distinguished University Professor of Chemistry, was chosen by the Colloid and Surface Chemistry Division of the American Chemical Society (ACS) as the first recipient of the Ralph K. Iler Award in the Chemistry of Colloidal Materials. Sponsored by E.I. du Pont de Nemours and Company, the award was established to recognize, encourage, and stimulate work in the chemistry of colloidal materials. The award was presented to Matijevic at the 205th ACS National Meeting in Denver, Colorado.

Matijevic has a special interest in colloids because many properties of matter depend not only on chemical composition, but also on the size and shape of the particles. Matijevic has developed a technique to make the particles all the same size, but with different shapes and chemical compositions. According to Matijevic, understanding the properties of colloidal materials is essential to eliminating them as a detriment to the environment and to producing these materials for many important uses.

R.M. German Honored by Metal Powder Industries Federation

Randall M. German has been selected by the Metal Powder Industries Federation to receive the Distinguished Service to Powder Metallurgy Award in recognition of his outstanding contributions to powder metallurgy technology.

German is currently the Brush Chair in Materials in the Engineering Science and Mechanics Department at Pennsylvania State University. Besides his academic duties, German is the technical director for the Particulate Materials Center, and has been involved in the creation of the Powder Injection Molding Consortium at Penn State. He received his PhD degree in materials science from the University of California–Davis. German’s research and teaching focus on particulate materials processing.

Sandia, SEMATECH Sign $100 Million Agreement to Aid U.S. Semiconductor Industry

Sandia National Laboratories and SEMATECH, a consortium of U.S. semiconductor manufacturers and the Department of Defense, have signed a multiyear cooperative research and development agreement (CRADA) aimed at keeping the U.S. microelectronics industry at the forefront of advanced technology. The cooperative work—which will aid in developing improved integrated-circuit manufacturing technology and equipment, reducing costs, and improving yield—covers six major categories: equipment benchmarking and engineering, contamination-free manufacturing research, equipment and software reliability, equipment modeling and design, materials and process analysis, and semiconductor process development.

An initial agreement between the two institutions, signed in 1989, created a Semiconductor Equipment Technology Center at Sandia as a new way for industry and government-funded laboratories to work together on microelectronics technologies. Continuing in 1992, another agreement established a Contamination-Free Manufacturing Research Center at Sandia to reduce particle contamination in semiconductor manufacturing. Now in 1993, the new CRADA will expand the existing reliability improvement projects, add new support in modeling and design, expand the activities of the Contamination-Free Manufacturing Research Center, and perform benchmarking and characterization of semiconductor manufacturing equipment.

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Gupta Receives Otto Schott Research Prize

Prabhat K. Gupta, a professor at Ohio State University in the Department of Materials Science and Engineering, has been awarded the 1993 Otto Schott Research Prize. The award was shared between Gupta and Dieter R. Fuchs of Würzburg, Germany for their outstanding achievements in basic and applied research into glasses and glass ceramics.

Gupta was honored for his contributions in advancing the science and understanding of glass, particularly in the structural relaxation of glass fibers and the indentation fracture mechanics of glasses. Beginning his research career in the spheres of phase separation and leaching of borosilicate glasses, Gupta subsequently worked on the strength of glass fibers and their chemical durability, the fiberization of melts, and glass homogeneity.

Following his studies at major universities in India and the United States, Gupta received a doctorate in materials science at Case Western Reserve University. He then continued his research work as a postdoctoral fellow at Yeshiva University in New York City, and at the Vitreous State Laboratory at Catholic University, Washington, DC. Subsequently, he was employed as a senior scientist at the Owens Corning Fiberglass Technical Center and as an associate professor of ceramics at Case Western University. Since 1986, Gupta has worked at Ohio State University.

Consortium Formed to Advance High-Performance Electronic and Optical Devices

The Advanced Research Projects Agency (ARPA) is funding a two-year program to study ways to advance the synthesis and processing of new electronic materials. The alliance, headed by Hughes Research Laboratories and Texas Instruments' Central Research Laboratory, includes three small businesses—EPI Corp., Superior Vacuum Technology, and J.A. Woolam Co.—as well as the Universities of Southern California, Colorado, New Mexico, and Virginia. Sandia National Laboratory is an associate member of the team. The industrial partners will contribute more than half of the $10 million funding.

The consortium is the first one approved under President Clinton's Defense Conversion Bill. The bill, through its Technology Reinvestment Program, targets accelerated development of military and commercial dual-use technologies and the conversion of defense technologies to the civilian sector, with emphasis on manufacturing technologies.

The program will focus on improving the performance of quantum well resonant tunneling devices and spatial light modulators for communications, high-speed computing, and signal processing. Also established will be "intelligent" material-processing techniques, including the use of expert systems, case-based reasoning and other computer-assisted methods. Key objectives include the

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development of sensors to enable real-time control of the MBE growth process; the improvement of models to predict device performance; and the fabrication and testing of new high-performance devices.

Gubser Receives Service Award

Donald U. Gubser, superintendent of the Materials Science and Technology Division at the Naval Research Laboratory (NRL), was honored with the Meritorious Executive, Senior Executive Service Award during a ceremony held at the Pentagon. Gubser was cited for "his sustained outstanding leadership and achievements in materials science and technology."

Gubser came to NRL in 1969. For the past five years, under his guidance as superintendent, scientists and engineers in his division have reoriented major research and development efforts and initiated new research projects in such areas as superconductivity, magnetism, composite materials, adaptive structures, processing science, and computational simulations.

Founder and chairman of the Navy Consortium for Superconductivity, Gubser now coordinates the Navy's research and development efforts in superconductivity. He also heads the NRL advanced materials development program and serves as the Navy's deputy chairman to the interservice Technical Panel on Advanced Materials. A co-claimant in NRL's patent application for the discovery of a high-temperature superconducting compound, Gubser is co-editor of the international *Journal of Superconductivity.*

Collaboration Investigates Reactive Scattering of Atoms and Molecules off Semiconductor Surfaces

The Webster Research Center of Xerox Corporation and Lawrence Livermore National Laboratory have begun a joint investigation into the behavior of atoms and molecules on microelectronic materials' surfaces. The goal is to develop fundamental scientific knowledge that can lead to improved performance in microelectronic devices used in a variety of industrial and consumer electronics products.

The three-year, $2.5-million project is funded jointly by Xerox and the Department of Energy through a cooperative research and development agreement (CRADA).

The Livermore lab, with its materials theory, simulation software, and computer power, extends the capabilities of the Webster Research Center's facility for studying etching, passivation (making a surface less reactive chemically), and the growth of thin films.

The joint research effort involves the use of quantum mechanical principles to understand what happens when a few atoms interact with a surface. The researchers then try to expand that understanding to include interactions of larger numbers of atoms, then a layer of atoms, and eventually quantities large enough to build microchips. In this way, they hope to learn how to optimize the processes needed to fashion new materials and devices.

The group hopes that the CRADA's work will lead to a quantitative theory of "reactive scattering" of atoms and molecules off semiconductor surfaces. Such a theory would permit scientists to predict the behavior of atomic particles that come into contact with a surface and cause a chemical reaction between the two materials. At this point, only theories for "nonreactive scattering" are in place. The capability to predict and control these reactions would permit microelectronic devices to be built atom-by-atom, leading to such improvements as higher-density and higher-performance optoelectronic and hybrid microelectronic circuitry, and advanced custom chip designs.

Broadly Tunable Laser Now Available

Researchers at Cornell University have developed a laser, called an optical parametric oscillator (OPO), which is tunable in wavelength from the ultraviolet to the infrared. According to C.L. Tang, who headed the group that patented and developed the technology, the OPO is useful in any application where different wavelengths of lasers are needed quickly. The ability to immediately select frequencies, or wavelengths, from all over a broad spectrum, is useful for applications such as detecting gas leaks or pollution monitoring because different molecules or materials absorb light at different wavelengths.

The basic idea for an OPO has been around since lasers were invented, but developing the technology has been difficult due to the lack of suitable materials needed for the oscillator. This OPO uses a newly discovered nonlinear crystal called beta barium borate (BBO). A nonlinear crystal splits an incoming photon into two photons whose wavelengths depend on the angle at which the incident light strikes the crystal. So, by rotating the crystal, the wavelength of the oscillator can be varied.

BBO was first identified in China in 1985, but the information was not published. Tang's group independently developed the technology, which was later transferred to Cleveland Crystals. Cornell Research Foundation licensed the OPO technology to Spectra-Physics Lasers Inc. of Mountain View, CA to manufacture and market the OPO system.

Correction

On the cover of its May 1993 issue, the *MRS Bulletin* published a picture of a hydrogen-terminated diamond tip indenting a hydrogen-terminated diamond surface. The cover caption neglected to mention that this photo was submitted by J.A. Harrison, C.T. White, R.J. Colton, and D.W. Brenner of the Naval Research Laboratory. The picture relates to their article in that same issue, "Atomistic Simulations of Friction at Sliding Diamond Interfaces."

Rosenstein Named AFOSR Senior Fellow

Alan H. Rosenstein has been elected a Senior Fellow of the Air Force Office of Scientific Research (AFOSR), Washington, DC. The Award is designed to identify the most exceptional program managers serving the AFOSR, to honor and reward them for their outstanding accomplishments, and to support and encourage the pursuit of continued excellence in research management.

Nanopowerhouses Patented by Researchers

E. Phillip Muntz and collaborators at the University of Southern California (USC) have patented a system to deliver energy efficiently—in the form of pushes—to extremely small structures.

A laser burst lasting one nanosecond heats an ultrathin layer of insulating material on the structure's surface, at the point where force needs to be applied. This, in turn, heats adjacent gas, resulting in increased pressure. If the walls cool rapidly after the burst of heat, then a short pressure pulse can result. The force is as much as 1,000 times that possible using electrostatic devices. Such laser-generated forces could throw tiny switches or, potentially, run microscopic motors.

Muntz, chairman of aerospace engineering at the USC School of Engineering, and Geoffrey R. Shiflett, associate professor of mechanical engineering, have just designed a switch system using this technology. □

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