Hoechst Reports High T_c Superconductor Work

Work on applications of the copper oxide high-temperature superconductors by Hoechst AG, Frankfurt am Main, has been reported in *Hoechst High Chem* by Helmut Eckhardt. Researchers there are using a melting process to produce bismuth-strontium-calcium-copper oxide superconductors. They are also conducting preliminary experiments with a partial melting process, drawing an yttrium-barium compound into monocrystalline rods. Eckhardt sees a simple early application of this process in the manufacture of current feeders for low-temperature superconductors, which require cooling almost to absolute zero. Such conductors are now supplied with current via ordinary copper cables, which heat up and increase the cooling requirement.

In the search for kilometer-long high-capacity power cables at Hoechst, the more conventional "powder in tube" method forms one avenue of investigation. A silver tube is first filled with a special superconductor powder, then drawn out into a thin superconducting wire. Current densities of approximately 13,000 A/cm^2 while maintaining superconductivity have been reported for cable runs of more than 200 meters. Another method being investigated at Hoechst, still in its early stages, involves vapor deposition of thin films of superconductors on metal tapes.

New Semiconductor Laser is Adjustable from the Mid- to Far-Infrared

In the new quantum cascade laser, charged particles first move up several energy levels, then cascade down step by step, emitting photons each time they hit a step. The laser can be tailored to emit light at a specific wavelength set at nearly any point over a spectral range from the mid- to far-infrared simply by varying the thicknesses of the layers that make the steps, using the same combination of materials.

The quantum cascade laser, described in the April 22 issue of *Science*, was invented at AT&T Bell Laboratories by Federico Capasso and Jerome Faist, in collaboration with Deborah Sivco, Carlo Sirtori, Albert L. Hutchinson, and Alfred Y. Cho.

"This is the culmination of a 30-year effort," said Capasso. "Piles of theoretical papers have been written over the years, but it took band-structure engineering and molecular beam epitaxy to make it happen." Pure quantum-confinement unipolar lasers were originally proposed by Rudy Kazarinov, who now works with Capasso, and Robert Suris, of the A.F. Ioffe Physico-Technical Institute in St. Petersburg, Russia.

The quantum cascade laser is a unipolar semiconductor laser: Only one type of charge (e.g., electrons) is needed for its operation. The electrons jump between two well-defined energy levels in the conduction band of the quantum wells, emitting photons of an energy equal to the energy difference between these levels.

This energy, which determines the wavelength of the emitted light, is controlled by the thickness of the quantum wells and the height of the energy barriers confining the electrons to these active regions. As a result, the wavelength is entirely fixed by quantum effects and can be continuously tailored over a very wide range by changing the active-layer thicknesses while using the same combination of semiconductor materials.

The emission wavelength of the first laser is 4.25 microns, and it can be tailored from roughly 2 to 100 microns. Other measured characteristics include powers as high as 130 mW in pulse operation and an operating temperature up to 125 K with 5 mW of power.

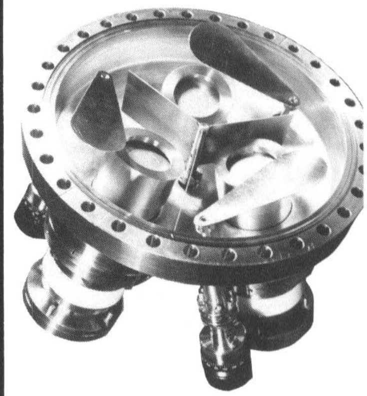
The semiconductor used in the quantum cascade laser is a sandwich of 500 layers clustered in sets of 20. Each set has 10 wells and 10 barriers. The multilayer material, including the quantum-well active regions, consists of alternated nanometer-thick AlInAs and GaInAs layers grown by molecular beam epitaxy on an InP substrate.

The new laser's compact size and flexibility suit it to a broad range of applications, say its makers. It should be useful for monitoring air quality, industrial process control, "free space" point-to-point communications, and spectroscopy.

$7 Million Effort Focuses on Electron-Beam Curing of Polymer Composites

Electron-beam curing of polymer matrix composites used to form parts for aircraft and aerospace applications—wings, stabilizers, engine housing, tail assemblies, fuselage sections, and aerospace structures—is the focus of a $7 million cooperative research and development agreement (CRADA). Participating partners include researchers at the Oak Ridge Y-12 Plant Centers for Manufacturing Technology and Sandia National Laboratories, and 10 industrial partners.

We wrote the book
Chapter 6



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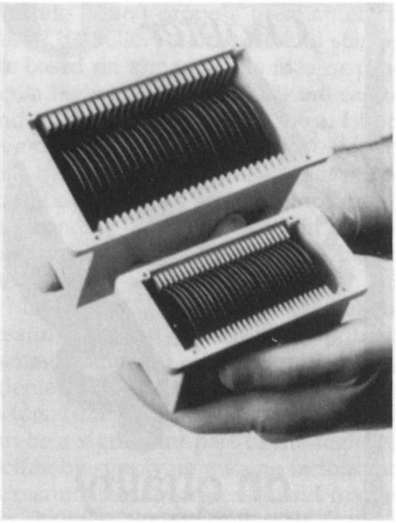

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Polymer matrix composites have broad applications for high-performance needs, but U.S. manufacturers have found large-scale production of polymer composites cost prohibitive. Current thermal curing technology requires long processing times, high energy consumption and expensive tooling, and it creates residual stress areas in the parts and produces volatile toxic by-products. Nonthermal electron-beam curing, which uses high-energy, high-power electrons to polymerize and cross-link composites, offers significant advantages: reduced manufacturing costs and curing times; simpler processing, lower cost tooling, improved part quality along with increased dimensional accuracy and performance, and reduced environmental and health concerns.

Six tasks will be performed under the CRADA:

- Development of electron-beam-curable materials,
- Establishment of a database for tracing manufacturing information and comparing material properties,
- Economic analysis of electron-beam technology,
- Development and evaluation of low-cost tooling options,
- Integration of electron-beam-curing processes and manufacturing technologies (including industrial retrofitting, minimizing manufacturing steps, and handling complex, large, or thick parts), and
- Demonstration and prototyping to evaluate cost, quality, and performance.

Participating members are as follows: Martin Marietta Energy Systems researchers in the Oak Ridge Y-12 Plant's Centers for Manufacturing Technology and at Sandia National Laboratories, Applied Poleramics, Ciba-Geigy, UCB Radcure, AECL Technologies, E-BEAM Services, IRT Corp, Boeing Commercial Airplane Group, Lockheed, Martin Marietta Aero and Naval Systems, and Northrop.

R.C. Bradt Receives AIME Educator Award

Richard C. Bradt, professor of materials science and engineering in the Mackay School of Mines of the University of Nevada-Reno has been recognized with the 1994 AIME Mineral Industry Education Award for "his outstanding achievements as a teacher, mentor, engineer, and researcher in the application of minerals in the refractories and metallurgical industries worldwide." He received the award at AIME's 123rd annual meeting in Chicago.

A graduate of the Massachusetts Institute of Technology and Rensselaer Polytechnic Institute in materials science and engineering, Bradt has held academic posts at Pennsylvania State University and the University of Washington. His research addresses the fracture mechanics of brittle materials and structural design

Recently Announced CRADAs

Rouge Steel Company (Dearborn, Michigan) and Lawrence Berkeley Laboratory (Berkeley, California) will improve electrogalvanized steel used in automobile manufacturing by enhancing the steel finish for painting while mantaining superior formability.

MKS Instruments (Andover, Massachusetts) and the Continuous Electron Beam Acceleration Facility (Newport News, Virginia) will develop a prototype ultrahigh sensitivity helium leak detector with a sensitivity of 10^3 to 10^4 over existing detectors. Such sensitive detectors could be used in critical vacuum environments in particle accelerators, magnetic fusion devices, and semiconductor processing equipment.

Catalytica (Mountain View, California) and the Naval Research Laboratory (Washington, DC) will use and evaluate a proprietary, high-pressure fluidized process to synthesize nanosize metal oxide powder for a wide range of applications, possibly including superconductors, electrooptical materials, semiconductors, ceramics fabrication, and corrosion coatings.

Park Scientific Instruments (Sunnyvale, California) and NIST intend to develop atomic force microscope technology for critical dimension metrology on semiconductor wafers as an alternative to current scanning electron microscope methods.

LoTEC Inc. (Salt Lake City, Utah) and Oak Ridge Y-12 Plant Centers for Manufacturing Technology will work to develop better ways to join low-thermal-expansion NZP ceramics to other materials or ceramics. The ceramics, a family of sodium zirconium phosphate ceramic materials and its crystal forms (such as calcium zirconium phosphate or barium zirconium phosphate), have a melting point above 1800°C. They can be used in ceramic diesel or gas turbine engines, burner nozzles, heat exchangers, and optics.

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with ceramics, refractories, and other brittle materials.

Bradt has previously been honored for his undergraduate teaching with the Anne and Matthew J. Wilson Award at Penn State and the American Ceramic Society/Ceramic Educational Council's Outstanding Educator Award.

Localization Seen as Key to Materials Failure

University of Illinois researcher Tarek Shawki says he is moving closer to understanding why materials fail under highly adverse conditions, a concern for manufacturers of high-speed machinery and other metallic products liable to break down as a result of excessive heat caused by sudden stress.

Applying theoretical mathematics and large-scale computer simulations to a wide variety of materials and loading conditions, Shawki and graduate student Harischandra P. Cherukuri found "localization" to be the key reason materials fail. When a system's kinetic energy approaches a threshold level, the material that makes up the system tends to deform in narrow zones. This, in turn, leads to structural failure. Localization of a deformation in a material involves a small section of a structure carrying increasing proportions of the applied loads.

Engineers currently use material tables to pinpoint crack-growth expectations depending on the material's resistance to crack growth. Shawki and Cherukuri hope to see a column headed "localization toughness" next to the table on fracture toughness. Based on their findings, the researchers now want to tabulate how to block the breaks that occur under high stress so they can "vaccinate the material against failure."

Multilevel Optical Disks Demonstrated

Scientists at IBM's Almaden Research Center have announced the demonstration of multilevel optical disks that could eventually provide huge gains in optical disk data storage.

The disks are made by stacking two or more recording surfaces on top of each other. The layers are glued together, with spacers providing a gap between the disks. Data is contained on any disk surface inside the stack and is read or written by moving the optical disk drive's focusing lens up and down to select the appropriate surface.

The laboratory demonstrations have shown that data can be read on two-, four-, and six-layer read-only disks and that data can be written and read on two- and four-layer write-once disks with essentially product-level signal-to-noise quality.

Each disk layer must be partly transparent so the optical drive's laser beam can penetrate to all the layers in the stack. Each surface must also have sufficient reflectivity to direct enough light back for the detectors to read the data accurately. The maximum number of surfaces in a disk stack is limited by the power of the laser, the transparency of the layers, and the cost of making multilevel disks compared with their single-surface competitors. The maximum number of layers in a writable disk would typically be less than

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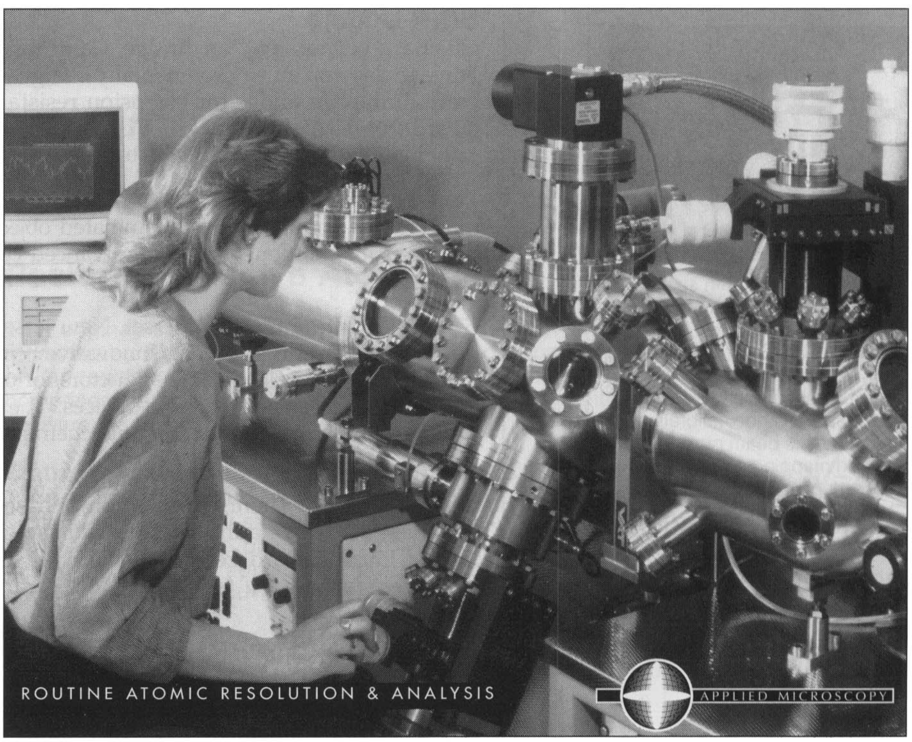

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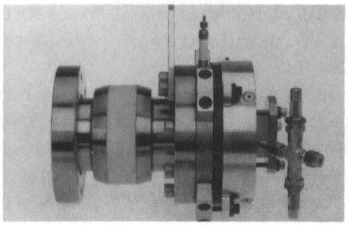

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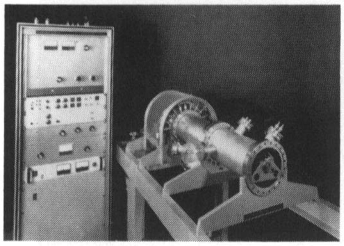

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in a CD-ROM because the writing process also requires that the disk materials absorb some of the laser light, thus reducing the transparency of each layer.

The movable lenses needed to focus on the different surfaces are already available in today's optical disk drives to maintain focus, even on warped disks. The two-level disks that were demonstrated require only minor adjustments to already existing devices, say IBM representatives. Although multilevel disks cannot be used in today's drives, IBM scientists anticipate that today's single-layer optical disks could still be usable in future drives designed for multilevel disks.

Ottino is APS Fellow

Julio M. Ottino, Walter P. Murphy Professor and chairman, Department of Chemical Engineering, Robert R. McCormick School of Engineering and Applied Science, Northwestern University, was elected to fellowship in the American Physical Society's Division of Fluid Mechanics. His citation reads: "For pioneering experimental and theoretical contributions to the understanding of fluid mixing and for exploiting and elucidating its relationship to chaos."

Thin Films Heated at One Million Degrees per Second

The University of Illinois reports that Les Allen, professor of materials science and engineering, and co-workers have been able to heat thin films of material at a rate of one million degrees a second and to stop within 10 degrees of a target temperature using a technique called electric thermal annealing. The technique warms thin films by supplying large amounts of electrical current—100 to 200 A—to a very small area.

The research, reported in Volume 64 of *Applied Physics Letters*, involved annealing low-resistance, stable electrical contacts to silicon using titanium disilicide as a bonding agent. Allen applied current through the silicon, monitored its resistance, and determined a one-to-one correspondence between resistance and temperature in order to determine the temperature of the sample to within 10°C during the heating.

The low heating rates now used in making electronic devices allow the formation of an unwanted compound from titanium disilicide, C49-titanium disilicide. Allen hopes to improve the heating system to rapidly attain temperatures as high as 1,100°C to eliminate the formation

SBIR Update

Chemat Technology (Northridge, California): Phase II award from the U.S. Air Force to develop an environmentally benign sol-gel surface process to pretreat aircraft aluminum alloys for corrosion resistance and adhesive bonding. Phase I award from NASA to search for conductive thermal control coatings with electrically modified optical properties by the sol-gel process.

Lone Peak Engineering (West Valley City, Utah): Phase II award from ARPA to develop and commercialize a laminated object manufacturing process to produce high-density components out of advanced ceramic materials in days rather than months.

EMCORE Corporation (Somerset, New Jersey): Phase II award from the Ballistic Missile Defense Organization/Innovative Science & Technology to investigate III-V nitride wide bandgap semiconductors for use in optoelectronic devices and visible-to-ultraviolet light-emitting devices. The company will use a hybrid growth process that combines metalorganic chemical vapor deposition and atomic layer epitaxy.

Quest Integrated (Kent, Washington): Phase I award from the U.S. Air Force to eliminate the use of adhesives in making rigid-flex substrates for printed wiring boards. Phase I award from the Ballistic Missile Defense Organization to develop a creep-resistant *in situ* (silicon nitride) ceramic composite free of glassy grain-boundary phases.

SI Diamond Technology (Houston, Texas): Phase I award from the National Science Foundation to investigate the feasibility of using its patented Amorphic Diamond Coating™ on the cathode of a field-emission microelectronic device that does not require the use of vacuum. Elimination of the vacuum would greatly simplify the construction of field-emission-based microelectronic devices.

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of the unwanted C49-titanium disilicide. Currently, the system can attain temperatures between 20 and 600°C.

The key advantage of the process, says Allen, is that all types of thin films can be heated using it, including metals, semiconductors, liquids, and possibly films that are biologically based.

Theoretical Models Predict Stability of "Rugbyballs"

Working with rugbyballs, the 70-carbon atom cousins of the soccer-ball-shaped buckyball, chemists at Sandia National Laboratories have developed theoretical models that quantitatively predict the stability of two forms of a chemically modified fullerene. Researchers Paul Cahill, Craig Henderson, Kenneth Gillen, and Celeste McMichael Rohlfing were able to demonstrate that their computations reflect precisely what is observed during fullerene reaction in the laboratory. Their results are reported in the April 15, 1994 issue of *Science*.

Last year, Cahill and Henderson reported that they had synthesized the simplest fullerene derivative—$C_{60}H_2$—and were able to accurately forecast that only one of 23 possible configurations would occur. These findings were published in the March 26, 1993, issue of *Science*.

Building on previous work with $C_{60}H_2$, they decided to work with C_{70} and compare and contrast its reaction behavior with $C_{60}H_2$. They ended up with a system that enabled them to predict what products would occur and which would be more stable. The quantitative model developed for $C_{70}H_2$ will be used for research into high-strength, lightweight materials.

University of Connecticut Receives Bearing Development Grant

The Institute of Materials Science and the Advanced Technology Center for Precision Manufacturing at the University of Connecticut has been awarded a three-year $650,000 research grant to develop advanced methods for manufacturing bearings made of superior materials by the Office of Naval Research.

The research will be conducted in the Institute of Materials Science by a team of scientists headed by Kenneth E. Gonsalves, assistant professor of chemistry, in partnership with Pratt & Whitney and the Naval Research Laboratory in Washington, DC.

Designed for strength and resistance to wear and fracture, the bearings are needed to meet an increasing demand for precision parts for aircraft engines, automobiles, and other machines with high-speed rotating components. Gonsalves will build new alloys of molybdenum, iron, chromium, and vanadium (M50 steel) by synthesizing fine powders. The powders will be used to produce bearings with surfaces up to 40 times more precise than conventional industrial grinding permits.

In addition, a Department of Defense augmentation grant of $220,000 awarded to Gonsalves will fund education and training for graduate research students during the three-year project. □

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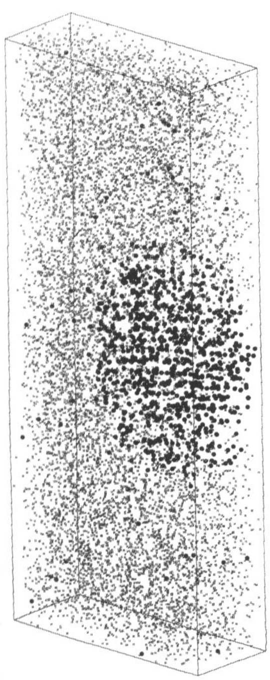

Analysis of a cobalt particle in an aged copper–cobalt alloy. Each dot represents a single atom, either copper (grey) or cobalt (black). The individual atomic planes in the particle are clear.

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