Diamond Coating Process Safeguards Infrared Optics

A diamond coating process developed at the Westinghouse Science and Technology Center, Pittsburgh, Pennsylvania, makes it possible to protect the soft windows of infrared sensors in high-speed aircraft from erosion by rain, dust, or sand.

The soft window materials, zinc sulfide and zinc selenide, are used because they are transparent to the infrared wavelengths most effective in tracking hot engine exhausts or aircraft surfaces. Standard, hard optical materials such as glass are not useful because they block these wavelengths.

So far, Westinghouse has produced small diamond-coated windows only about an inch and a half in diameter, but work on larger windows is under way. Field tests may be possible next year.

A technique called optical brazing overcomes the problem of severe chemical and mechanized incompatibility of diamond on zinc compounds and reduces image distortion created by the uneven growth surface. The diamond coating is predeposited on a silicon wafer, then the diamond side of the wafer is moored to a glass bonding layer, and this sandwich is fixed to the zinc compound window. Finally, the silicon outer layer is removed, exposing the highly transmitting, optical-quality diamond nucleation surface. The bonding medium is a chalcogenide glass, selected for its excellent mechanical and optical compatibility with the two materials. The diamond layer is produced by microwave plasma-enhanced chemical vapor deposition.

Immediate application calls for protection of infrared optics, important for military and commercial aircraft, the space program, and even drug interdiction. Future uses could include visible-spectrum windows in advanced missiles and spacecraft, protection of photovoltaic cells in space, and more down-to-earth applications like shatter-proof plastic eyeglasses, watch crystals, or scratch-free mirrors. Presently, however, the visual range has a slight residual fuzziness caused by scattering, which will require further research.

Two Groups Find Screw Dislocations Central to $YBa_2Cu_3O_7$ Film Growth

Researchers from two continents are using advanced tools of observation to better understand the behavioral characteristics of high-temperature superconducting thin films, including their ability to carry higher current densities. The work attempts to observe how good films are actually made rather than simply try to improve characteristics by trial and error.

One of the groups, a team from Los Alamos National Laboratory, studied the surface microstructures of c-axis-oriented films of $YBa_2Cu_3O_7$ by using scanning tunneling microscopy and atomic force microscopy (*Science,* March 29). They found that films may actually nucleate as islands and grow by adding material.

"We now understand how these films grow in some detail," said Ian Raistruck. "That is, we understand how the individual grains are built up as time goes by."

"For the first time, we have shown what the real microstructure of the films looks like," said Raistruck. "If you use only a scanning electron microscope, they look pretty smooth. The intermediate scale we have with the scanning tunneling microscope gives a better picture of the real microstructure of the films."

What the Los Alamos team found is that these are not single-crystal films, a popular term sometimes erroneously used to refer to high T_c thin film work. "They are clearly composed of little spiral grains," said Raistruck.

The work implies that grains or columns grow by adding atoms to a spirally expanding step on the top surface of the grain. Film growth proceeds by the island growth mechanism rather than by the addition of new layers. The result is columnar grains, each containing a screw dislocation at the center. The dislocations extend from the substrate interface all the way to the free film surface. The Los Alamos team believes this may largely explain the superconducting properties of the thin films.

By finding where screw dislocations occur, researchers hope to discover how flux is pinned. By actual observation, they hope to understand effects of high temperature annealing and other processing techniques.

Yet the Los Alamos team itself notes that there are relatively few screw dislocations compared with the vortex density at fields in the mixed state. "The density of the screw dislocations is not high enough to account even for the current densities that we do see in these films," observed Rainstruck. "If you calculate the number of flux lines that can be pinned by the number of screw dislocations we have seen, it certainly doesn't account for 10^7 A/cm^2." Whatever contributions there are of screw dislocations to pinning would seem to be restricted to a few Tesla.

"Our hypothesis is that it is the low-angle grain boundaries in this spiral growth structure that are perhaps providing pinning centers," said Raistruck. "The result is that you end up with a network, or cells, of low-angle grain boundaries, or edge dislocations, rather like you do in niobium titanium, which are very effective in flux pinning."

One conclusion of the Los Alamos group was that the density of dislocations is higher in thinner films. "Apparently, the dislocations annihilate themselves as the films grow," said Raistruck.

It is unclear whether thallium or bismuth high T_c films have characteristics similar to the yttrium-barium cuprates. "Thallium thin films do not have an analogous growth process," said Raistruck. "We haven't done much with bismuth, but I believe they are more like thallium than 1-2-3."

A separate team at IBM Zurich also observed screw dislocations in YBCO films (*Nature,* March 28). (One member of the IBM Zurich team was Georg Bednorz.) This group based their observations on results from a scanning tunneling microscope. They found large groups of screw densities in sputtered thin films, exceeding the number in the substrates by three to four orders of magnitude. The group was able to observe screw dislocations with densities of about 10^9/cm^2 in seven of nine samples investigated.

The IBM Zurich group found that screw dislocations may account for critical current density in magnetic fields less than 400 g. Above 200 g, the flux line density exceeds that of the dislocation so that the behavior of the critical current density, J_c, in high magnetic fields cannot be explained by the observed screw dislocations alone.

The IBM researchers assume that the dislocation density and surface roughness of the films may largely be controlled by varying the substrate surface or parameters of film growth.

Both groups hope to continue to find clues about how the growth mechanism and higher critical current densities are achieved. One question the Los Alamos group hopes to pursue is how common the growth mechanism is with regard to the various ways of making thin films. Another is how much the microstructure depends on the growth conditions and how well it can be controlled.

Materials Physics Becomes APS Division

The Materials Physics Topical Group of the American Physical Society officially became a division last October, joining 12 other divisions represented on the APS Council. Divisional status was granted on the basis that the Materials Physics Topical Group represents a large and increasing

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sub-unit in the Society. Topical groups do not have voting status on the Council but divisions do, so divisional status increases recognition and visibility of materials science within the physics community.

Terms of the new APS constitution automatically grant divisional status to groups with membership greater than 3% of the total APS membership. However, the Materials Physics Group, although larger than this percentage, proactively pushed to become a division before the new rules were in place. The Materials Physics Division is already larger than five other established divisions. At the March APS Meeting, the Materials Physics Division had the second largest number of papers, Condensed Matter Physics having the most. APS members may join one or more divisions or groups for a small fee.

Tom Picraux, former chair of the Materials Physics Group during its transition to divisional status, said that some people were initially concerned that the Materials Physics Division would compete with the Condensed Matter Physics Division (the largest subgroup of APS). Instead, he said, the groups are working side by side to strengthen representation in both areas. Although there is some overlap between the areas, condensed matter physics is directed more toward studying the physical principles or phenomena that occur in solids, irrespective of the materials in which they occur, while materials physics emphasizes the study of particular materials, and how the materials can be modified and processed to capture and control phenomena.

Sandia to Build Major Materials Research Laboratory

A $27.9 million Integrated Materials Research Laboratory (IMRL) will be built at Sandia National Laboratories to help develop new critical materials for military and industrial needs. The 140,000-square-foot facility will integrate new basic research in tailored materials with advanced development functions of electronic devices, components, and sensors, augmented by emergent computer modeling techniques.

Construction began in March, with completion scheduled for December 1992. The IMRL site is outside Sandia's main secure technical area in Albuquerque to enable easier access to cooperating researchers from private industry and universities.

Workers will conduct research in:

- Semiconductors. The concentration will be on compound semiconductors and strained-layer superlattices.
- Superconductors. New high-T_c superconductors for unique electronic and microwave properties will be investigated experimentally and theoretically.
- Ceramics. Microstructures will be studied and tailored for strength, toughness, electrical properties, and microwave absorption.
- Altered metals. Materials will be designed for better resistance to friction, wear, erosion, corrosion, and diffusion.
- Dielectric materials, including tailored structures with improved electrical, mechanical, and noncharring properties.
- Microsensors. Optical, infrared, chemical, force, acceleration, and pressure sensors of novel types will be investigated.
- Optical devices. Scientists will study solid-state lasers, diodes, nonsilicate optical fibers, and seals.
- Surface and interface physics and chemistry. This will include the surface physics and chemistry of nucleation and growth of epitaxial thin films.

Also, computer modeling work will take place in the areas of molecular and lattice dynamics, surface physics and chemistry, and electronic structure.

Of the Department of Defense's 1990 list of 22 critical technologies, the IMRL will directly target at least seven: photonics, semiconductor materials, microelectronic circuits, passive sensors, superconductivity, materials and processes, and high-density materials.

Sandia officials say the IMRL is also intended to continue and improve efforts at successful technology transfer of Sandia developments to industry. Much of the unclassified materials research and components development activity proposed for the IMRL is of relevance to U.S. industry, and so collaboration and technology transfer will be stressed from the outset.

Douglas G. Brookins, University of New Mexico geology professor, expert on radioactive material and nuclear waste, and highly respected instructor, died April 30 at the age of 54.

Brookins graduated summa cum laude from the University of California at Berkeley with a BA in geology and held a PhD in geology from the Massachusetts Institute of Technology. Before joining UNM as a professor in 1971, he was an associate professor of geology at Kansas State University. Brookins served as geology department chairman at UNM from 1976 to 1979. He established a distinguished program in isotope geochemistry, and also developed an interdisciplinary graduate program in the Water Resources Administration. The UNM Foundation has established a memorial scholarship to honor his work.

Also a part-time research scientist at Argonne and Oak Ridge National Laboratories, Brookins served on many panels concerning technical issues of geochemistry and waste management and disposal. He was internationally recognized as an authority on issues of radioactive and chemical wastes, geology of uranium deposits, and radiometric dating of rocks and geologic events. Brookins was especially interested in the migration of radionuclides and the geologic evidence for types of migration, using his experiences at Oklo (Africa, where a natural uranium deposit went critical over a billion years ago) and elsewhere to find analogues for systems at other sites. He served on several environmental committees as well.

Author, co-author, or editor of approximately 500 publications, he wrote one of the first books about radon, *The Indoor Radon Problem.* Known for independence of thought, Brookins supported the Waste Isolation Pilot Plant and also argued successfully for the inclusion of geochemical considerations in remediation strategies for the nation's abandoned uranium mill tailings.

Brookins, who belonged to numerous honorary and professional organizations, was actively involved in developing the international symposia on the Scientific Basis for Nuclear Waste Management in the late 1970s and early 1980s. He was a key force in combining the interdisciplinary needs of that community with those of a fledgling MRS. He chaired the 1982 MRS Fall Meeting symposium on the Scientific Basis for Nuclear Waste Management and was a member of the symposium steering committee for many years.

Optical Microscope Achieves Probe-Size Resolution

Structures generally considered too small to resolve with optical imaging are visible using a new optical microscope probe developed at AT&T Bell Laboratories. The technique, described in the March 22 issue of *Science,* relies on optical fibers to efficiently shine light in proximity

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to a sample, generating images with resolution of ~12 nm, four times smaller than the usual diffraction barrier of $\lambda/2$.

The effectiveness of the near-field scanning optical microscope (NSOM) relies on the proximity of the light to the sample, shifting the resolution limit from the wavelength of the probe to the probe size.

The probe is produced by drawing a single-mode optical fiber while heating it with a laser. The resulting structure tapers uniformly from the original fiber to a tip with a flat end face perpendicular to the fiber axis. The sides are coated with aluminum, leaving the end face as a transmissive aperture. Apertures from 20 to 500 nm have been produced.

The probe delivers light efficiently to the aperture since all the radiation remains bound to the core until a few microns from the tip. A larger signal emerges from the fiber than in previous designs, and the elimination of background light results in better resolution. Illumination is scanned by the microscope with resolution on the order of the probe size.

Although an electron microscope can also resolve these small objects, it often damages living tissue and other radiation sensitive materials. And while electron microscopes can cost up to $1 million, the AT&T design may be in the $20,000 range.

Five Universities to Establish Center for Computer Graphics and Scientific Visualization

A five-year, $14.68 million grant from the National Science Foundation and the Defense Advanced Research Projects Agency to five universities will establish the Science and Technology Center for Computer Graphics and Scientific Visualization. Researchers will engage in basic research to improve ways to link computers with visualization, and they will work with U.S. companies to enhance the country's lead in commercial computer graphics. The grant will be augmented by millions of dollars from the universities and their state governments, along with donations of equipment from manufacturers.

The aim of the program is to derive realistic computer images from sophisticated internal models of physical reality and emphasize the viewing of world models that obey the laws of physics.

Practical uses of the technology include detailed ultrasound internal organ imaging, "walking through" and adjusting technical simulations (such as an engine in operation), display of fracture propagation in equipment parts, radiation therapy for cancer patients, or visualizing the simultaneous movement of skin, muscle, and bone.

Basic research will cover advanced modeling and display techniques, 3-D user interfaces, high-speed parallel graphics computers, and interactive controls for animation and simulation. Scientists will standardize software to allow the rapid spread of advanced techniques.

Members of the center are Brown University, the California Institute of Technology, Cornell University, the University of North Carolina, and the University of Utah. To help transfer the center's knowl-

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edge to industry, center leaders are planning visits between universities and industrial laboratories. An external advisory board will include representatives from the four major initial corporate sponsors, Digital Equipment, Hewlett-Packard, IBM, and Silicon Graphics.

NAE Re-elects White as President

The National Academy of Engineering (NAE) re-elected Robert M. White to a third four-year term as president. White, an internationally recognized expert in meteorology and oceanography, has served as president of the 1,600-member association since 1983.

Also re-elected for a four-year term was NAE Foreign Secretary Gerald P. Dinneen, former vice president for science and technology at Honeywell Inc. In addition, NAE members re-elected two councillors and elected one new councillor, all for three-year terms. The re-elected councillors are Thomas E. Everhart, president, California Institute of Technology, and Mary L. Good, senior vice president of technology at Allied-Signal Inc. Newly elected to the NAE Council is Erich Bloch, former director of the National Science Foundation.

Argonne Spins Off Advanced Ceramics Firm

Inexpensive, formable ceramics stronger than steel will be manufactured and marketed by a new company spun off from Argonne National Laboratory. James E. Moore, president and chief executive officer of Nanophase Technologies Corporation, Darien, Illinois, projects initial products to be fiber-optic connector components, high-temperature engine seals, and gas filters that help control quality during semiconductor manufacturing. Nanophase Technologies expects to have its first products on the market in about a year. In January 1991, it completed construction of a pilot facility to test and refine its manufacturing process.

Richard W. Siegel, one of the Argonne researchers, said the new materials are stronger, more ductile, and easier to form than conventional ceramics. Objects are formed by combining grains less than 50 nanometers, which are made by vaporizing a source material in the presence of a gas, then condensing the vapor.

Studies at Argonne and Northwestern University have shown that as grain size gets smaller, nanophase copper and palladium become five time stronger than in their conventional state, Siegel said.

Nanophase ceramics become increasingly formable and less brittle with smaller

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grain size, Siegel said, and become easier to machine without cracking or breaking. "Sintering temperatures for ceramics can be reduced more than 1,000°F. Shrinkage during sintering is greatly reduced, so you get an object that needs less machining to achieve its final shape," Siegel said.

Nanophase ceramics are also well suited to doping to control properties of materials like semiconductors for electronics. The porosity of nanophase ceramics can be closely controlled, he said, making them useful as molecular filters and sieves and as material for catalysts.

R.W. Cahn Elected Fellow of Royal Society

Robert W. Cahn, senior associate in the Department of Materials Science and Metallurgy, University of Cambridge, England, was recently elected a Fellow of the Royal Society. He is currently involved in research on intermetallics and is writing a book on the subject. He is editor-in-chief of various publishing projects in materials science, including textbooks, reference works, and journals. Cahn has been a principal editor of *Journal of Materials Research* since before it started publication and has also written technical pieces, book reviews, and Material Matters for the pages of the *MRS Bulletin*. Now retired, Cahn was previously professor of materials science and dean of engineering at Sussex University, England, and then a professor at the University of Paris-South, France.

Four German Groups Collaborate in Solar Energy Study

A publication of the German Research Service, *Special Science Reports*, announced the teaming of four groups, the German Aerospace Research Institute (DLR), the Research Center Jülich (KFA), the Berlin Hahn-Meitner Institute (HMI), and the Fraunhofer Institute for Solar Energy Systems (ISE), in a major push to seek interdisciplinary ways to reduce dependence on nuclear and fossil fuels, and increase solar energy's share of the total energy consumption from the current 8% to 50% by 2050. The collaboration is financially supported by the Federal Ministry for Research and Technology.

HMI is focusing on converting light into electrical as well as chemical energy. Materials more advanced than the present standard silicon are being studied, including chalcopyrites (semiconductors made up of three components), pyrites such as FeS_2, and complicated metal compounds called chevrel phases.

One group at KFA is concentrating on improving the stability, optoelectric characteristics, and interfaces of amorphous semiconductor layers. Another KFA group is studying fuel cell and water hydrolysis technology to store and retrieve energy derived from solar cells.

DLR is considering mass utilization of solar-thermal power stations, with an eye toward export potential. Three areas of research are involved: efficient energy conversion, domestic solar energy consumption, and solar hydrogen.

ISE is involved with projects for practical local applications, developing, with industry, new processes for the production of cast and band-type polycrystalline silicon for photovoltaic systems. Also, in the conceptual stage are decentralized systems that would furnish up to several kilowatts of power. From a program for small devices, solar-powered clocks and pocket calculators have already appeared in the market. Also, demonstration houses supplied by solar energy exist. □

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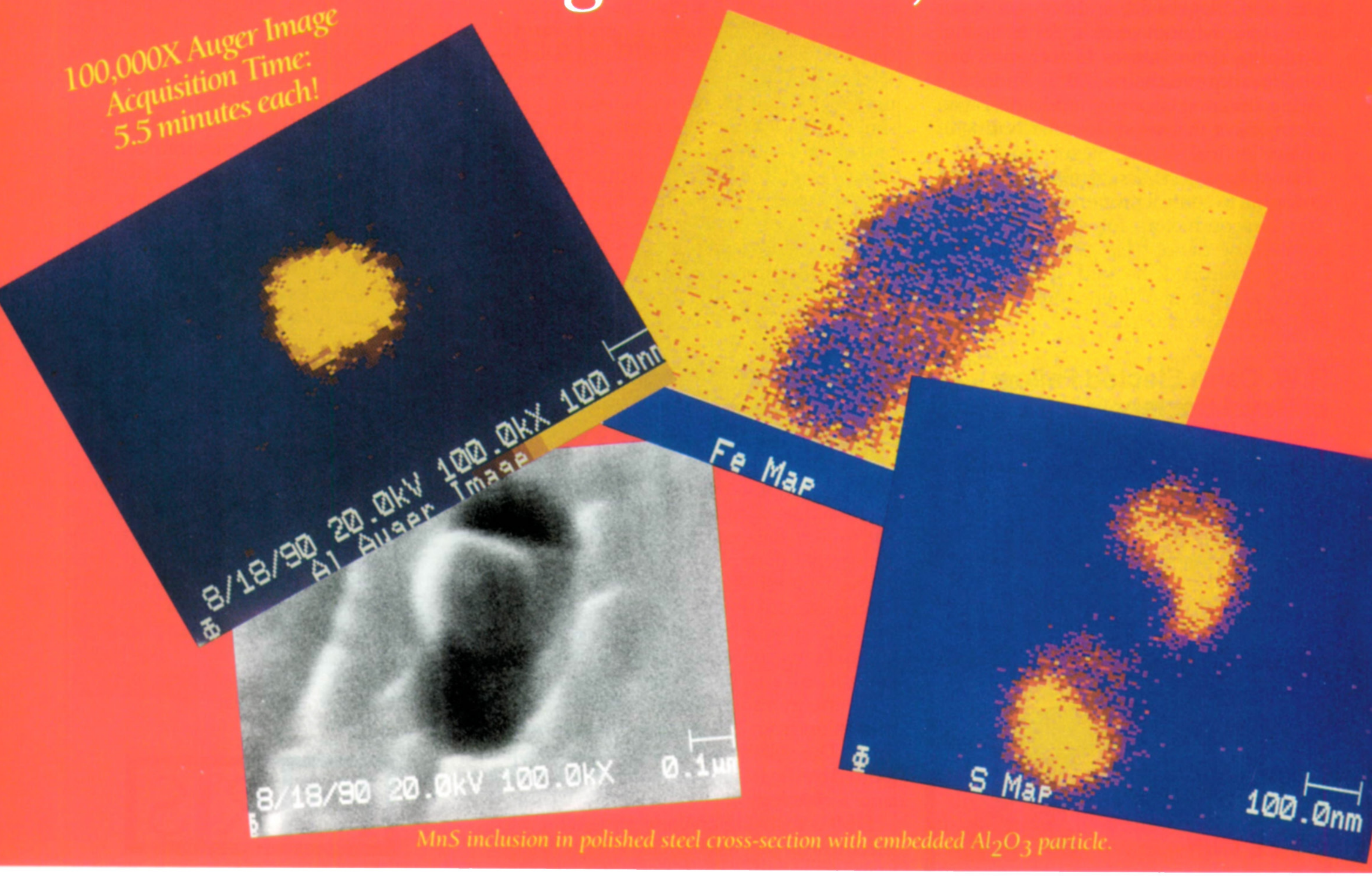

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