Conference Shows Progress in Ion Beam Modification of Metals

Many people associate the ion beam modification of materials surfaces primarily with the semiconductor industry, where such modification, particularly implantation of dopants, has seen commercial application. For well over two decades, however, those working with energetic beams of ions of all the elements have also investigated their effects on metals. Researchers associated with this work met at the eighth in a series of international conferences on the surface modification of metals by ion beams (SMMIB '93) during the week of September 13, 1993, in Kanazawa, Japan.

The conference comprised about 45 talks—nearly half of which were invited lectures—and more than 120 posters presented by researchers from the United States, China, Japan, and several European countries. The topic covered in most detail, and one that has become the traditional subject of such conferences, was the implantation of nitrogen into ferrous alloys, including typical steels. This treatment mainly improves tribological properties, a result which was a purely empirical one in the "early days." The 1993 conference demonstrated that a great deal more scientific understanding of the underlying processes has been gained, and a far wider variety of implantation conditions and property enhancements is now being pursued.

The physical phenomena altered by ion beams, usually for the better, included (in addition to friction and wear properties) corrosion in various environments, adhesion of thin films, optical properties, crystal structures and metastable phases, impurity diffusion, trapping and redistribution, diffusion barriers, and even micromachining. In addition to direct ion implantation, ion beam mixing of thin-film layers, ion beam stitching or knitting for adhesion of thin films, ion-beam-assisted deposition, and ion beam modification of structures, including amorphization, were described. Other papers addressed the implantation of carbon with nitrogen or alone, and the formation of carbides and carbonitrides.

Many variations of techniques were described: implantation of multiple ions sequentially or simultaneously, implantation at a sequence of different temperatures, implantation through sacrificial layers in order to reduce the effect of sputtering on dose limitation, and variation of the energies and angles of incidence in order to affect the texture of ion-beam-assisted deposited films.

Several beneficial ion implantation applications have been demonstrated in the past, perhaps the most well known being ion implantation on the cutting edges of razor blades. Ion implantation has also been successfully applied to nuclear cladding and to bearings in Naval helicopters, as well as to motor racing bearings, tool bits, and orthopedic implants, among other applications. Massive application of this technology in the marketplace has yet to occur, however.

Presentations at the Kanazawa meeting showed that the facilities needed to demonstrate the efficacy of ion beam modification for commercial applications are still being installed and that industrial acceptance is perhaps on the horizon. It would seem that many technical barriers have been overcome and that up-front capital investment is manageable for this technology. In the United States and China in particular, several laboratories are reportedly pursuing scale-up of implantation facilities which would involve the purchase and installation of large dedicated ion implanters designed to run in a limited energy range using one or a few ion species to treat large fabricated parts. It must still be demonstrated to manufacturers, however, that substituting ion-beam-improved items into their product lines would be supported by market demand adequate to sustain the full product cycle.

The next meeting, the Ninth Annual Conference, will be held in Spain in 1995. Perhaps more insight into the question of insertion will have been gained by that time. The 1993 meeting was organized by M. Iwaki of the RIKEN Laboratory in Saitama. Proceedings will be published in the journal *Surface and Coatings Technology* (Elsevier).

AIP Corporate Associates Meet at SUNY/Buffalo

The 1993 fall gathering of the Corporate Associates of the American Institute of Physics held October 25–26 at the State University of New York at Buffalo was hosted by the University, Calspan Corporation (a Corporate Associate of AIP), and the Medical Foundation of Buffalo. The program featured presentations on a broad range of topics as well as tours of the hypersonic test facility at Calspan and research facilities at the SUNY/Buffalo campus.

The theme chosen for the meeting—"Be There Before You Get There"—was an appeal to the ever-increasing importance of computer simulation of physical systems before or, in fact, without ever, doing experiments. In this context, M.G. Dunn of Calspan's Advanced Technology Center spoke on the simulation and experimental duplication of hypersonic bodies, covering shock wave phenomena, hot ion chemistry, communication blackout on re-entry, turbine blade performance, and the like. Brian Flannery of Exxon dealt with simulating global climate change phenomena. After enumerating the plethora of factors that influence global climate and discussing whether a serious greenhouse effect is in the offing, Flannery essentially concluded that inadequate scientific understanding of many important phenomena currently contributes to ultimate uncertainty in simulations. A perhaps more vexing contribution to this uncertainty, said Flannery, is the inability to predict human behavior regarding industrial effluence and introduction of cleaner technologies.

George Lee of SUNY/Buffalo explained the University's program to simulate the effects of earthquakes on engineered structures. He pointed out significant progress in one-dimensional modeling of the effects of various types of earth movements. However, realistic simulation is only now entering the two-dimensional regime, and real earthquakes, as Lee emphasized, are three-dimensional. The message was that engineers must still "guess" based on earth movement patterns observed in prior quakes and apply this to proposed structures and structural reinforcements in order to estimate the effects and required safety factors.

Massimo Fiscetti of IBM's T.J. Watson Research Center discussed miniaturization in electronics. He explained that the limits now being approached—as physical dimensions decrease to where statistical analyses of carrier behavior are no longer adequate—require the full Boltzmann transport equation. Devices that depend on the ballistic behavior of electrons will be the norm, and sizes will trend to the ultimate limit of perhaps a few hundreds of atoms for the active region of a device. He noted that continual extrapolation of current trends to the year 2020 would imply one atom per bit in a digital circuit and operation with an energy dissipation of kT. Both limits are unphysical, he said, also pointing out that as miniaturization continues, capital investment for manufacturing facilities for the new devices will increase at such a rate that the trend must inevitably level off soon. Fiscetti was among several presenters to invoke prescient statements by Richard Feynman. He quoted, "There's plenty of room at the bottom," indicating that premature predictions of limits of smallness are inappropriate. Fiscetti's computer simulations of how devices will operate at the smallest sizes lead him to believe that qualitatively new device mechanisms will be seen before ultimate limits are reached.

During an evening ceremony on October 25 at Buffalo's Albright-Knox Art Gallery, Leonard S. Cutler, Curt A. Flory, and Robin P. Giffard of Hewlett Packard Laboratories in Palo Alto, California were honored with AIP's prize for international applications of physics. The three were cited for applying a wide range of basic physics and electronics to the design and improvement of frequency and time standards. They were instrumental in introducing a cesium clock that is the most accurate, stable, reliable commercial time-keeping device known. The Institute presented its annual award for science writing to Hans Christian von Baeyer for his book *Taming the Atom*. The Berlin native, a professor in the Physics Department at the College of William and Mary, has received several previous honors for his writing on science for the public, including AIP's science writing award in 1989.

Protein crystallographer and one-time NASA mission specialist Lawrence J. DeLucas of the University of Alabama closed the evening event. His pictures showed a fascinating close-up and intimate view both of the scientific preparations for performing protein crystal growth in the microgravity environment of space and of his personal experiences during training, launch, and orbital flight of a U.S. shuttle mission.

The second day was devoted to discussions of science policy and included additional talks on the frontiers of physics. Herbert Hauptman of the Medical Foundation of Buffalo gave a detailed description of the "minimal principle" in x-ray crystallography. Using detailed formulae, he explained why it is difficult to invert a measured diffraction pattern to the actual physical locations of the diffracting atoms in a large and complex crystal-lattice structure. In so doing, he showed how the assumption (which existed in the first half of this century) that a diffraction pattern alone is insufficient to derive the complete structure, is wrong and that the phases in the scattering process can be managed mathematically through the minimal principle to derive structures, after all. In a logical extension of Fiscetti's talk the day before, Trey Smith of the IBM T.J. Watson Research Center, described progress in microprocessors which has resulted from improvements in device miniaturization, speed, and parallel computing. Continuing with Feynmen's "room at the bottom" idea, Max Lagally of the University of Wisconsin-Madison gave attendees a view of the nanoworld through the scanning tunneling microscope (STM). Although nanotechnology was coined as a word in the mid-1970s, he noted, it was not seriously pursued until the mid-1980s. Now structures can be observed and manipulated using atomic probes such as the tunneling microscope. An intriguing video about the motion of vacancies on the stepped surface of silicon during crystal growth as seen via STM augmented Lagally's presentation.

Staying in the microworld, Noel MacDonald of Cornell University spoke on the micromachines currently being fabricated, primarily through sophisticated lithographic techniques. He described small free-moving structures, cantilevers, motors, and methods to thermally, electrically, and mechanically isolate these devices. MacDonald also appealed to a 1983 Feynman quote that acknowledged the possibility of creating such devices but doubted their eventual use. MacDonald's presentation made clear that sensors and sensor arrays, accelerometers, field-emission tips, microsprings, and improved microsized tunneling and atomic force microscopes are possible. The technical part of the program concluded with a presentation by Philip Lubin of the University of

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California-Santa Barbara on results from the COBE experiment, a satellite that searches for dark matter in the universe.

Presentations on science policy in the United States were given by Charles Shank, director of Lawrence Berkeley Laboratory, and by Roland Schmitt, chairman of AIP's governing board.

Shank discussed the changing roles of the national laboratories, noting the conversion from a larger to a smaller defense-oriented research mission and greater emphasis on environmental cleanup and remediation. These factors, as well as budgetary constraints, have placed the national laboratory system under great stress, and changes are to be expected, said Shank. He described the existing system with some eight multiprogram and several single program laboratories, explaining a bit about their creation.

Shank pointed to partnerships with the private sector as the principal new ingredient that will help the laboratories make the transition into the next century. The national need corresponding to the augmented mission of the laboratories is U.S. industrial competitiveness, he said. Shank described several government, university, and industry partnerships with Lawrence Berkeley Laboratory which have produced commercially viable technological advances.

Pointing out that the national laboratory system supports large user facilities, essentially as a public trust, Shank said that rising facility budgets can erode the ability of research budgets to effectively pursue other parts of the laboratories' missions. He predicted that projects will more likely be "meso" than mega-projects such as the superconducting super collider.

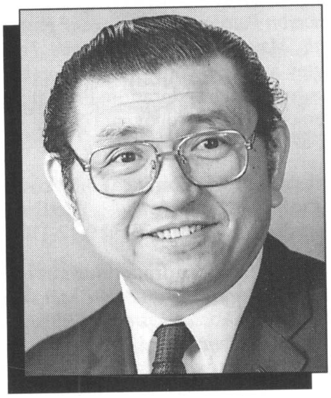
Roland Schmitt's view of U.S. science policy combined his experience as an upper manager in industrial research (General Electric) and as president of a respected research and engineering university (Rensselaer Polytechnic Institute). Schmitt said that the title of his presentation, "Rationale for Public Support of Science in the Post Cold War Era," might as well have been "Fractals in Foggy Bottom" or "Chaos on Pennsylvania Avenue." He described the views of public figures in science and politics on the science enterprise and its utility to the country. Quoting Senator Barbara A. Mikulski (D-MD) and Representative George E. Brown Jr. (D-CA), and referring to the opinions of such prestigious physicists as P. Anderson and L. Letterman, he noted that common ground is a difficult place to find.

He listed four rationales for doing research: (1) the public's desire to answer basic questions and find universal truths, (2) the American pioneer spirit which seeks the next frontier, (3) the utility of science as a source of wealth, and (4) the political appeal of many projects and programs. He was quick to note that the list was in decreasing order of importance to the scientist and increasing order of importance to the politician. In order to find common ground, scientists ought not assume that everybody shares their enthusiasm for the practice or results of basic research, Schmitt advised. The challenge is not simply to educate others about science, but to allow ourselves to be educated about the priorities of those who support science, he said.

Included in national needs and goals, said Schmitt, are such items as competitiveness in a global context, defense conversion, creation of high-quality jobs, and the preservation and improvement of the environment and health. He provided broad statistical evidence that the funding trends, such as those associated with defense conversion for example, will place great pressure on the research enterprise. His central message to scientists interested in pursuing what has been termed "curiosity driven" basic research is that one *can* operate on a common ground with those who fund research and still be allowed to do good science. It is necessary, however, to choose basic areas "inspired by the tough problems" which are somehow related to, but not directed by, national needs and goals.

For further information on the Corporate Associates meeting or on the AIP Corporate Associates program, contact the American Institute of Physics at American Center for Physics, One Physics Ellipse, College Park, MD 20740-3843; phone (301) 209-3100, fax (301) 209-0843. Or, contact Dr. Benjamin Snavely, Chairman, AIP Corporate Associates Advisory Committee, at the National Science Foundation, 4201 Wilson Blvd., Arlington, VA 22230; phone (703) 306-1810. □

Franklin F.Y. Wang, professor of materials science and engineering at the State University of New York at Stony Brook, died on August 30, 1993, after a short illness.



Since 1991, he had been on leave to the Materials Research Division of the National Science Foundation, where he was responsible for reviewing programs in metals, ceramics, and also in electronic materials. Known for his research in the electric and magnetic properties of ferrites and related rare earth compounds, Wang published important work on the properties of glasses, crystal growth, and solid-state reactions.

He worked for the A.O. Smith Corporation and then for the Sperry Research Corporation. In 1966 he joined Stony Brook to help build the Materials Science Department. He chaired the department from 1970 to 1973. Several times he was selected for outstanding faculty teaching awards. In 1978 he and Pat Herley initiated an NSF program, Women in Science, which provided graduate training in materials science for women who had left work to raise families. In 1983 he founded the journal Materials Letters. His research resulted in a number of books, including *Introduction to Solid State Electronics*, *Materials Processing: Theory and Practice*, and *Impurity Doping Processes in Silicon.*

Born in Nanjing, China in 1928, he later came to the United States and graduated from Pomona College with a BA in chemistry. He also earned a master's degree in glass technology at the University of Toledo, and a PhD degree in ceramics at the University of Illinois.

Wang was a fellow of the American Ceramic Society and the American Institute of Chemists. He was an MRS Councillor, a senior member of the Institute of Electrical and Electronic Engineers, and a member of the American Physical Society, American Chemical Society, and the Association of Crystal Growth. □