as a joint project with Rochester General Hospital. Other research areas under way include: design improvement for titanium dental root implants, *in-situ* testing of bioceramic materials for short-and long-term biocompatibility, microstructural evaluation of bioceramic interfaces for bone-ceramic joining and dental decay correction, piezoelectric ceramics for signal detectors and diagnostic and healing biosystems, and carbon-carbon and other composites for bone implants that encourage tissue growth.

Institute director Fischman, a specialist in structural ceramics, was primarily responsible for forming the High Performance Ceramics Laboratory at the College, where his group developed a zirconia femoral endo head for total hip replacements.

High-Performance Microwave Circuits Built on Soft Substrates

New methods for making state-of-the-art, high-performance microwave circuits on a soft, flexible substrate could be used by makers of radar systems, avionics electronics, and other systems where large, high-precision hybrid circuits are needed.

Using the techniques, researchers at Sandia National Laboratories accurately patterned and etched circuit conductors, achieving 1/4 mil tolerances and linewidths as narrow as two mils. Features can be machined into the soft substrate with one-mil accuracies. Precision features were needed in the circuits because of the high-frequency requirements of the synthetic aperture radar (SAR) system for which they were developed.

In developing the higher frequency SAR, Sandia researchers needed a substrate with a lower dielectric constant to reduce potential losses of the radio frequency signal. They also needed a more mechanically forgiving material than commonly used ceramics to allow them to build larger circuits without the substrate cracking. These circuits, up to three times larger than normal hybrid circuits, were needed to accommodate a greater number of functions than found in other SAR systems. The hybrid circuits used in the SAR system are assembled with a combination of silicon circuits and surface-mounted capacitors and resistors, making them similar to a miniature printed circuit board. While previous radars had five to six smaller microcircuits, the new SAR uses 18.

The researchers chose a commercially available laminate substrate called Duroid, a composite material consisting of a ceramic and Teflon matrix with a laminated copper sheeting topside and a laminated brass backplate, giving the materials the rigidity needed for fabrication processes.

Both the tolerances of the conductor linewidths and their edge definitions had to be precisely controlled to permit high-fidelity electrical operation over large bandwidths. To accomplish this, researchers had to develop a more accurate method of removing the extraneous copper. They developed a new "spin-spray" etching technique for use with ferric chloride that controls copper removal while the etchant is being sprayed. They also overetch the copper to partially remove it from under the photoresist pattern resulting in straighter conductor side walls.

Use of a softer, resilient substrate also required the development of new processes to attach components, such as resistors, capacitors, isolators, attenuators, and thermistros to the material—and attach leads to copper conductors. The processes, including welding, epoxy bonding, soldering, and surface mounting, were developed for a reliable attachment to the circuit and were sequenced so that attachment and cleaning processes for one component did not affect the reliability of the previous attachment process. In some instances, the component was mounted through the dielectric directly to the brass backplate for electrical or heat sinking considerations. □

LETTERS TO THE EDITOR

To the Editor:

DOE Center of Excellence for Synthesis and Processing of Advanced Materials

The item entitled "Sandia to Lead Center of Excellence for Synthesis and Processing of Advanced Materials" which appeared in the Research/Researchers section of the November 1991 issue of the *MRS Bulletin* needs some correction and elaboration. This Department of Energy Center is a coordinated effort among the following DOE laboratories: Ames Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, University of Illinois Materials Research Laboratory, Lawrence Berkeley Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, Pacific Northwest Laboratory, and Sandia National Laboratories.

Sandia is responsible for the overall coordination of the effort. The initial research activities of the Center are grouped under the following five focus areas: (1) atomically-structured materials, (2) complex polymers, (3) advanced ceramics and ceramic films, (4) nanophase materials, and (5) emerging materials and processes.

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Center Coordinator