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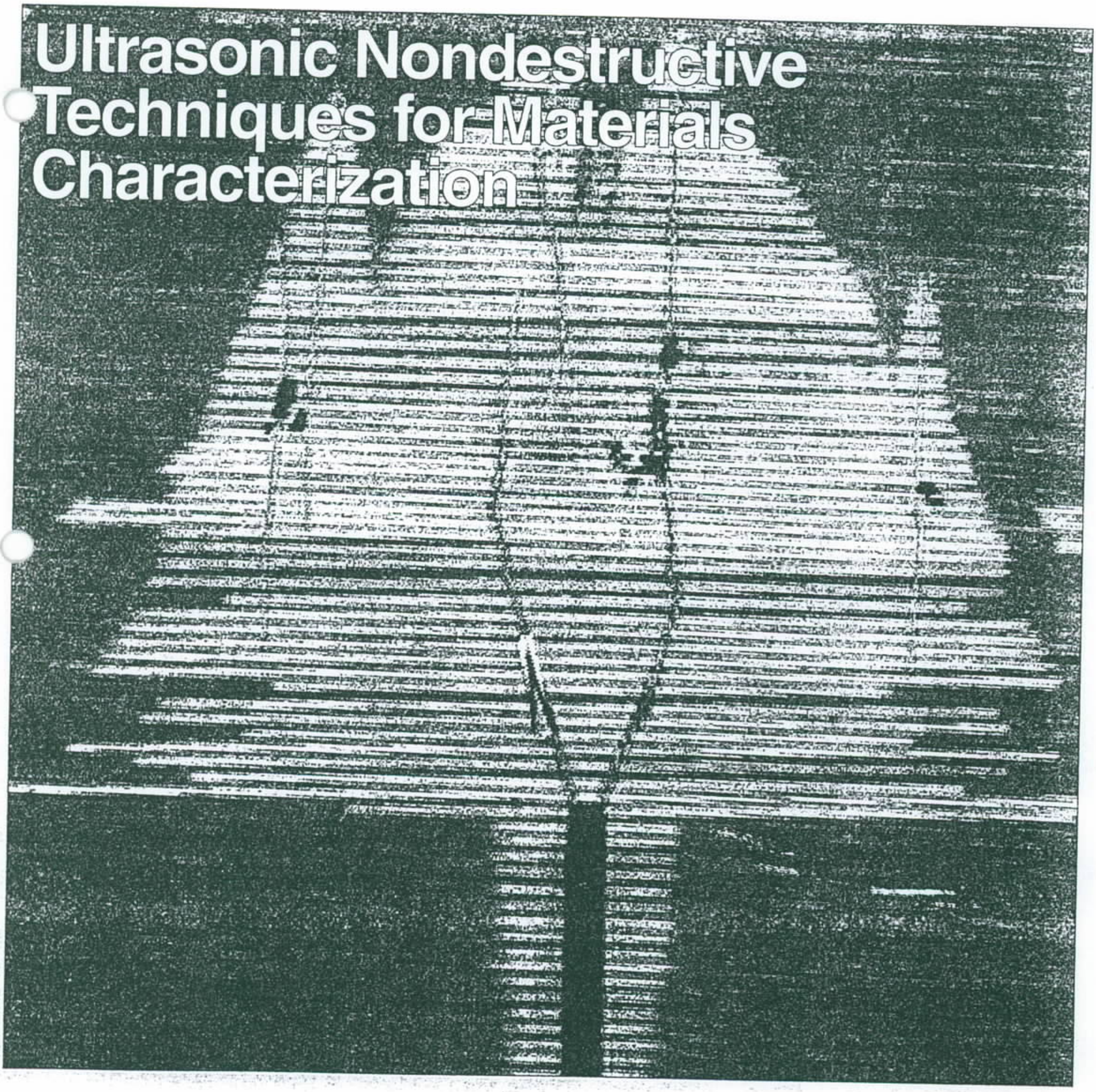

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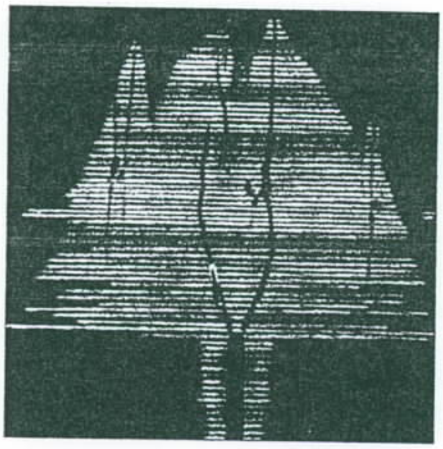

ON THE COVER: An ultrasonic image, based on time-domain scanning acoustic microscopy, of a single-edged, diamond-saw-notch, four-ply, unidirectional, SiC (SCS-6) fiber-reinforced titanium (Ti-15Mo-3Nb-3Al-0.2Si wt%) matrix-composite specimen. The specimen was subjected to 10^4 thermomechanical cycles over 36 days. The image indicates that two matrix cracks initiated from the corners of the diamond-saw notch and propagated perpendicular to the fibers and load direction. Further, the ultrasonic image shows the extent of interface oxidation, which has a characteristic mushroom shape. The image shows that the damage occurs after the matrix crack progresses past an unbroken fiber and exposes the interface to environmental attack. The thermomechanical-fatigue test as well as the development of the ultrasonic-characterization technique were performed at the Air Force Materials Directorate, Wright Laboratory, Wright-Patterson Air Force Base, Ohio. For more about this topic, see "Ultrasonic Characterization of Surfaces and Interfaces" by Stanislav I. Rokhlin and Theodore E. Matikas on p. 22.

Ultrasonic Nondestructive Techniques for Materials Characterization

Theodore E. Matikas and Robert L. Crane,
Guest Editors

Characterization of materials properties is critical for the understanding of materials behavior and performance under operating conditions. Tailoring materials properties, which are functions of the materials states, is essential for advanced product design. The need to characterize materials for a myriad of applications has spurred the development of many new methods and instruments. Unfortunately many of these characterization tools require destructive sectioning. Also many characterization techniques do not provide key information about material parameters in their operating environments. An ideal characterization tool would provide data about the material properties that are related to micro-and macrostructure without destructive sectioning. Such data can only be obtained using nondestructive-evaluation (NDE) methodologies. Therefore NDE is essential for almost any industrial product. Nondestructive evaluation has become an integral part of materials research because it enables the determination of material parameters (such as micro- and macrostructure, stress, physical properties, and defects) at nearly any point, line, surface, or volume element of interest and at nearly any state during the life of the material. Nondestructive evaluation is based on many different methods that rely on elastic waves, penetrating radiation, light, electric and magnetic fields, chemical sensing, etc. The large number of potential methods makes NDE not a single field but a synergism of many scientific and engineering disciplines. Since it would be impractical here to present all the new NDE methodologies with application to materials research, this issue of *MRS Bulletin* focuses exclusively on those ultrasonic techniques that are increasingly important in materials characterization.

Ultrasonic methods are used to characterize elastic properties and microstructural states by introducing low-level, high-frequency stress waves into the material under examination. Ultrasonic waves propagate in the material, interact with the microstructure, and subsequently are detected. The characteristics of the ultrasonic waves are modified as they travel through the material due to reflection, scattering, and attenuation. The detected signal is displayed, processed, and interpreted in terms of the internal structure of the material under investigation based on its relation to the input wave. Although ultrasonic methods have been used for several decades in materials characterization, recent advances have produced high-resolution imaging as well as quantitative elastic-property measurement capabilities. The articles presented here offer a survey of a few of these advances in ultrasonic methods, as well as the types of problems being addressed by these techniques.

The first article of this survey, by S.I. Rokhlin and T.E. Matikas, offers an introduction to various ultrasonic measurement methods for the characterization of materials surfaces and interphases. Applications discussed in this article include quantitative characterization o thin films and interphases in layere materials and high-temperature com posites. Various methods have bee described for elastic property determi nation of thin films and interphase Imaging techniques for internal map ping of damage have also been pre sented. These techniques can provide quantitative description of environmen tal effects, due to fatigue and oxidation on interfacial layers and on the adhesio of these layers to the substance.

The next article, by G.A.D. Briggs an O.V. Kolosov, is an introduction to acous tic microscopy. This ultrasonic techniqu provides both imaging and quantifica tion capabilities and can be used fo characterizing the near-surface elasti properties of a material. This articl summarizes applications of the tech nique in various areas including imag ing of surface/subsurface damage evaluation of interfaces between a protec tive coating and its substrate, measure ment of small cracks, characterization o interfaces in composites, and quantita tive measurements of elastic propertie of surfaces. This article also provides short introduction to Brillouin spectros copy, which is finding increasing appl cations in the characterization of surfac and thin layers of electronic materials.

Atomic force microscopy (AFM) h received great attention in the materia community for surface profiling an imaging capabilities. The article b K. Yamanaka is devoted to the descrip tion of a new modification of AFM termed ultrasonic force microscopy which offers quantitative measurement of elastic properties with nanoscale sp tial resolution. Recent progress in th area includes applications of ultrason force microscopy for characterization crystal-lattice defects and interfaces composites.

M. Urchulutegui describes a new tech nique, termed scanning electron-acoust microscopy or thermal-wave micro copy. This technique is based on the ut lization of an electron beam to generat stress waves in the material and offe unique characterization capability wi no required surface preparation of th sample. The technique can be used t measure many material parameters suc as thermal and elastic properties, fe roelectric and ferromagnetic domain doped layers and p-n junctions in sem conductors, and sample heterogeneity. also can detect mechanical subsurfa microdefects. The technique can be a plied to metals, semiconductors, cerar ics, polymers, and magnetic materials.

The article by R.L. Thomas and L.D. Favro describes the principles of photoacoustic microscopy, which is based on the detection of sonic waves generated by the absorption of light and its application to materials evaluation. The advance of this technique lies in noncontact and remote implementation. The authors discuss theoretical and experimental fundamentals and the evolution of the technique leading to the use of thermal waves for imaging subsurface defects such as corrosion, delaminations, etc.

Conventional ultrasonic techniques generally necessitate a coupling medium between the probe generating the ultrasonic waves and the material. However in some cases (i.e., characterization of materials in a high-temperature environment or inspection of small or complexly shaped components that may be inaccessible with conventional ultrasonic transducers), noncontact methods are required. Laser-based ultrasonic techniques provide a solution to this problem. The article by A. Safaeinili, A.D.W. McKie, and R.C. Addison, Jr., discusses the use of laser-based ultrasound to evaluate surface hardness of materials. ☐

Theodore E. Matikas

Robert L. Crane

R.C. Addison, Jr.

Andrew Briggs

L.D. Favro

Theodore E. Matikas, Guest Editor for this issue of *MRS Bulletin*, received his BS degree in mechanics from the University of Thessaloniki, Greece, and his MS and PhD degrees in applied mechanics and materials from the Université de Technologie de Compiégne, France. In 1988 he joined the research staff at the Commission of the European Communities, General Division XII. In 1991 he became a National Research Council Associate at the U.S. Air Force Wright Laboratory, Materials Directorate, Wright-Patterson Air Force Base, Ohio. In 1993 he began his present appointment at the University of Dayton Research Institute. Matikas is responsible for the on-site research program at the Materials Directorate, Wright-Patterson, dealing with the development of advanced-characterization capabilities for the evaluation of aerospace systems. He is involved in efforts to improve efficiency in the development of these materials as well as providing a basic understanding of the mechanisms that determine behavioral properties. He has developed analysis and imaging techniques for the characterization of surfaces and fiber-matrix interfaces in metal-matrix and ceramic-matrix composites. His current research focuses on theoretical and experimental studies for the assessment of microdamage, including environmental degradation of interfaces in composite materials and high-cycle fatigue damage in metallic alloys. He has participated in the North Atlantic Treaty Organization Advisory Group for Aerospace Research and Development Structures and Materials Panel for metal-matrix and ceramic-matrix composites. He is a member of many professional societies. Matikas has authored over 70 technical publications and has served as chair in several national and international conferences. He can be reached at the U.S. Air Force Wright Laboratory, Materials Directorate, WL/MLLP, 2230 10th St., Wright-Patterson Air Force Base, Ohio, 45433-7817, USA; phone 513-255-9808; fax 513-255-1363; e-mail matikat@ml.wpafb.af.mil.

Robert L. Crane, Guest Editor for this issue of *MRS Bulletin*, received his BS degree in ceramic engineering and MS and PhD degrees from the Ohio State University in materials science. In 1969 he joined the Materials Directorate of the Wright Laboratory, Wright-Patterson Air Force Base, Ohio, and has held a variety of research posts in materials science in the directorate. Crane has performed basic and applied research in polymer-, metal-, and ceramic-matrix composites, biomimetics and infrared optics, and various disciplines within nondestructive evaluation. His current research focuses on theoretical and experimental studies of the nondestructive-evaluation methods for the determination of damage to the microstructural high-performance alloys, detection and quantification of corrosion, and the application of infrared techniques to medical diagnostics. Crane is a member of several professional societies associated with materials science and engineering. He has authored over 90 technical publications and has served as the chair in several national and international conferences. He can be reached at U.S. Air Force Wright Laboratory, Materials Directorate, WL/MLLP, 2230 10th St., Wright-Patterson Air Force Base, Ohio 45433-7817, USA; phone 513-255-9828; fax 513-255-9804; e-mail cranerl@ml.wpafb.af.mil.

R.C. Addison, Jr., received a PhD degree from Stanford University. He then worked at American Optical Corporation, was a member of the staff at Ginzton Labs, Stanford University, and joined Rockwell in 1978. He spent the 1985–86 academic year at University College London working on the nondestructive measurement of thin-film adhesion. At present his main interest is in the development of laser-based ultrasound instrumentation. He is working on applications of this technology to the nondestructive inspection of large-area composites and parts having complex curvature as well as to the control of manufacturing processes. He is also active in developing high-frequency ultrasonic NDE techniques for materials to be used in hypersonic aircraft. Addison is a member of the Institute of Electrical and Electronic Engineers and the Acoustical Soci-