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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-5 fiber-reinforced titanium (Ti-15Mo-3Nb-3Al-0.25Si wt%) matrix-composite specimen. The specimen was subjected to 10⁴ 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. Rokhin and Theodore E. Matkis on p. 22.
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 of thin films and interphases in layered materials and high-temperature composites. Various methods have been described for elastic property determination of thin films and interphases. Imaging techniques for internal mapping of damage have also been presented. These techniques can provide a quantitative description of environmental effects, due to fatigue and oxidation on interfacial layers and on the adhesion of these layers to the substrate.

The next article, by G.A. Briggs and O.V. Kolosov, is an introduction to acoustic microscopy. This ultrasonic technique provides both imaging and quantitative capabilities and can be used for characterizing the near-surface elastic properties of a material. This article summarizes applications of the technique in various areas, including imaging of surface/subsurface damage evaluation of interfaces between a protective coating and its substrate, measurements of small cracks, characterization of interfaces in composites, and quantitative measurements of elastic properties of surfaces. This article also provides a short introduction to Brillouin spectroscopy, which is finding increasing applications in the characterization of surface and thin layers of electronic materials. Atomic force microscopy (AFM) has received great attention in the material community for surface profiling an imaging capabilities. The article by K. Yamanaka is devoted to the description of a new modification of AFM termed ultrasonic force microscopy, which offers quantitative measurements of elastic properties with nanoscale spatial resolution. Recent progress in the area includes applications of ultrasonic force microscopy for characterization of crystal-lattice defects and interfaces in composites.

M. Uychutegui describes a new technique, termed scanning electron-acoustic microscopy or thermal-wave microscopy. This technique is based on the utilization of an electron beam to generate stress waves in the material and offer unique characterization capability without required surface preparation of the sample. The technique can be used to measure many material parameters such as thermal and elastic properties, ferroelectric and ferromagnetic domains, doped layers, and n- and p- junctions in semiconductors, and sample heterogeneity, also can detect mechanical subsurface microdefects. The technique can be applied to metals, semiconductors, ceramic...
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The article by R.L. Thomas and L.D. Favin describes the principles of photoacoustic microscopy, which is based on the detection of acoustic waves generated by the absorption of light and its application to materials evaluation. The authors discuss theoretical and experimental fundamentals and the evolution of the technique leading to the use of thermal waves for imaging sub-surface 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. Saito and A.D.W. McKie, and R.C. Addison, Jr., discusses the use of laser-based ultrasound to evaluate surface hardness of materials.

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R.C. Addison, Jr., received a Ph.D degree from Stanford University. He then worked at American Optical Corporation, was a member of the staff at Ginzo 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 ultrasonic instrumentation. He is working on applications of this technology to nondestructive evaluation of ceramics for large plane areas and for the control of manufacturing processes. He is also active in developing high-frequency ultrasonic techniques for materials to be used in hypersonic aircraft. Addison is a member of the Institute of Electrical and Electronic Engineers and the Acoustical Society of America.