CONF-9608146--1

Computerized Microtomography for New Applications

G. Ice
ORNL

A. Thompson
LBNL

The advent of high brilliance synchrotron sources has stimulated the development of advanced x-ray microtomography and has made it possible gain new insights into materials properties. However, materials research problems challenge existing tomographic techniques. High spatial resolution is required to identify and characterize microstructure in real materials. Good elemental sensitivity is required to study the effects of microalloying. Three-dimensional crystal texture, strain and phase information is required to understand advanced materials. In addition, materials samples can include a wide range of elements, can come in unfavorable geometries, and sometimes will require dynamic measurements of their three dimensional structure.

One challenge for x-ray microtomography, is the measurement of low concentrations with good spatial resolution and high elemental sensitivity. In several alloy systems, the addition of 10 to 100 ppm can have a major effect on ductility, impact resistance, creep-rupture strength, radiation stability or weldability. For example in Fe_3Al and iridium alloys, weld properties are sensitive to ppm of Zr and Th. The study the 3-dimensional distributions in microalloy samples, will require fluorescence tomography techniques. Fluorescence tomography has been applied to tomography of plasma confinement in fusion devices, and some proof-of-principle experiments for fluorescence x-ray microtomography have been performed with simple phantoms and low Z (biological) samples. For example Paul Boisseau completed a dissertation in 1978 under Lee Grodzins which used x-ray fluorescence microtomography to study the iron distribution in a honey bee.

Another challenge to standard x-ray microtomography is the study of elemental distributions in planar structures where elemental sensitivity is required in one or two dimensions, but the spatial sensitivity in all three dimensions is not required. For example, the elemental distribution through the thickness of a plastic rocket fuel liner was recently needed to study the effect of elemental contamination on the liner adhesive properties. Because of the small concentrations, standard tomographic techniques were not possible. Depth profiling was accomplished by crossing the x-ray sensitive volume with the incident beam. This technique allows three dimensional elemental distributions to be built up with good resolution in two dimensions (determined by the transverse beam dimensions) and with poor resolution in the third dimension. Similarly, total-external-reflection techniques can be used to depth profile the elemental distribution with nanometer depth resolution in smooth samples, and standing wave techniques can be use to study surface contamination with sub-angstrom resolution on perfect single crystals.

For a large class of materials, crystalline structure, strain and texture are critical to the materials properties. Recent work has now demonstrated the possibility of extending x-ray microdiffraction to the study of three dimensional crystallographic distributions. Efforts are now underway at the APS, ALS, SSRL and NSLS to further develop x-ray microdiffraction and x-ray microdiffraction tomography. The measurement of strain and texture in three dimensions will have important applications to the study of high J_c high T_c superconductors, the study of second phase distributions and texture in composite materials, and the study of crack and void evolution in structural and electronic materials.

Another frontier for x-ray tomography is the development of dynamic or real-time measurements. Gunivier and Stock have recently studied crack propagation by observing the evolution of a crack through repeated cycling of the specimen. By monitoring the evolution of cracks, phases, diffusion, void growth and other microstructural properties it will be possible to greatly extend our understanding of materials properties.

Although there are many challenging materials samples where more powerful microtomography techniques are needed, for some specimens, existing techniques provide very valuable new information. One almost ideal specimen is an advanced nuclear fuel sphere for intrinsically safe reactor fuel. These small spheres are composed of a nuclear fuel kernel surrounded by buffer layers of graphite and a containment barrier of SiC. X-ray tomography allows a nondestructive evaluation of the sphere to study defects, inhomogeneities and interfaces. Not only do the tomographic measurements avoid the contamination problems associated with traditional sectioning methods, but because the tomographic measurements are nondestructive it is possible to study the evolution of the spheres through various environmental insults such as simulated melt downs.

Research performed in part at the Oak Ridge National Laboratory Beamline X-14 at the National Synchrotron Light Source, Brookhaven National Laboratory, sponsored by the Division of Materials Sciences and Division Chemical Sciences, U.S. Department of Energy under contract DE-AC05-96OR22464 with Lockheed Martin Energy Research Corporation.

DISCLAIMER