Triangulation Method for Grain Depth Measurement Using Polychromatic Micro-Beam Radiation.

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Introduction

A detailed knowledge of the pre-existing residual strains and strains due to applied loads is imperative in the study of composite material behavior. Mechanical models predict stress based on parameters such as: material modulus, processing temperature, thermal expansion coefficients, and applied loads. However, the accurate prediction of the strains at a mesoscopic level or at the granular level is often difficult due to anisotropy, complexity in the structural arrangement, and the number of calculations required. Recent developments in the X-ray source and optics at beamline 7.3.3 at the Advanced Light Source have enabled accurate determination of the strains within specific grains of a polycrystalline material.[1] Use of polychromatic X-rays along with a precise positioning system and focusing lens system provides sub-grain strain contours in (x, y) across many grains.[2] Described here is a method of determining the position of a grain along the direction of the beam (z) by tracing diffracted beams. Thus, grains may be placed in space for observation of 3-D interactions and reactions to stress.

Method Used

Polychromatic X-ray radiation of 2-14 keV was chosen for Laue micro-diffraction in the 90° transmission geometry (Fig. 1).[1, 2] A model single fiber composite consisting of aluminum (A356) and sapphire fiber was mounted on the translation stage in a frame for stress application. Diffraction patterns at up to 1500 points distributed over an area of 0.5 mm x 0.3 mm of the sample perpendicular to the incident beam were used to produce grain specific strain results.

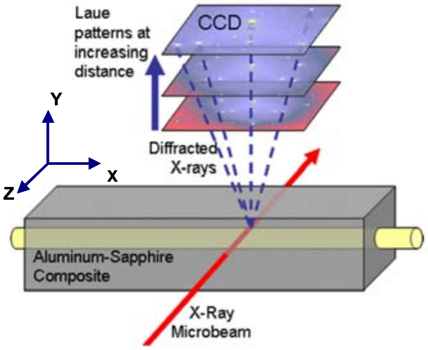

Fig. 1 Setup of Laue diffraction and triangulation

For the third dimension of the spatial location (depth within the sample along the beam), two or more images of a specific point on the sample and increasing vertical distance of the CCD are required. Diffraction spots from the same grain may then be triangulated to calculate the path of the diffracted beams and, therefore, depth of the grain. Here the CCD (perpendicular to the incoming beam) was displaced in ten 5 mm steps and the diffraction patterns recorded. A relation between the 2D strain information and grain depth was established using the available grain orientation angles with respect to the beam.

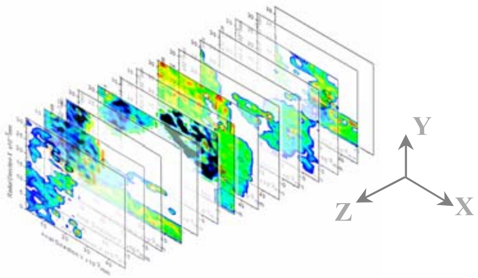

Fig. 2 Strain contours in (x, y) placed at depth (z).

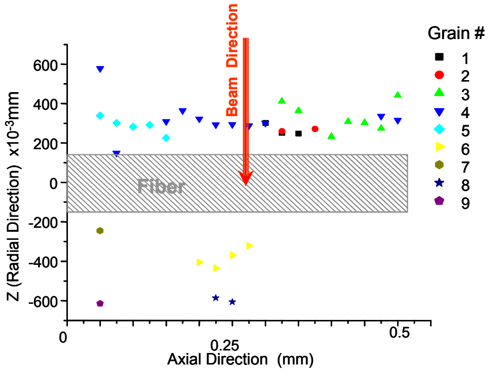

Fig. 3 Grain depth (along the beam) with reference to fiber depth from triangulation.

Results

Individual grain shape and strain distribution over every grain has been determined (Fig. 2). High-resolution grain morphologies were obtained including strain and orientation. The distribution of strain at the matrix-fiber interface was observed with an average strain accuracy of 2×10^{-4}. Triangulation along with Laue diffraction provided grain specific strains with spatial location of the grain. Spatial information related to depth, through triangulation, provided grain depths down to an accuracy of 10 microns as shown in Fig. 3.

Discussion

More grains were recorded towards the front of the sample than the back due to absorption. Going from 1-D (n patterns) to 2-D requires n x m patterns; from 2-D to 3-D requires n x m x h patterns, where h equals the number of CCD height steps. Along with grain orientation, location, and shape in (x, y); the shape of diffraction spots in Al help identify each unique grain.

Acknowledgements

The Advanced Light Source is supported by the Director, Office of Science, Office of Basic Energy Sciences, of the U. S. Department of Energy under Contract DE-AC02-05CH11231.

References

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