Dislocations arrangements in Shock-Recovered Al Single Crystals from White Beam Diffraction

R. Barabash, [1] G. Ice [1], W. Liu, [2] J. Belak, [3] M. Kumar [3]

[1] *Oak Ridge National Laboratory, Oak Ridge, TN U.S.A.;* [2] *Advanced Photon Source, Argonne, IL U.S.A.;* [3] Lawrence Livermore National Laboratory, Livermore, CA *U.S.A.*

Introduction

Strong shock waves result in the transition from elastic to plastic compression. Regions with voids and geometrically necessary dislocations are formed causing local lattice curvature. A spatially resolved diffraction method with a sub micrometer-diameter beam and 3D differential aperture technique is applied to understand the arrangements of voids, geometrically necessary dislocations and the elastic strain gradient distribution in samples of Al (123) single crystal shocked to incipient spallation fracture

Methods and Materials

The x-ray synchrotron measurements were made with a 3D X-ray crystal microscope [1] based on polychromatic (white) microbeam with the energy range ~6 - 25 keV on beamline 34ID at the Advanced Photon Source. Dimensions of the beam were 0.5 by 0.5 μm^2 with a penetration depth of ~ 500 microns.Differential aperture x-ray microscopy (DAXM) was used to obtain depth-resolved information about the local structure. A sketch of the shocked Al single crystal and the geometry of initial and diffracted white beam radiation and the microbeam geometry are shown in the Fig. 1c.

Results

The polychromatic x-ray microdiffraction (PXM) technique was applied to the complicated dislocation structure arising from the shock induced plastic/elastic deformation of the Al (123) single crystal. The microbeam-Laue diffraction reveals several distinct zones located at different depths under the shockfront. Pronounced streaking of Laue images is observed near the crater and near the back side of the shock-recovered Al single crystals (Fig. 1). Streaks are almost parallel to the shock direction. In white-beam diffraction, the length and orientation of the streak is a function of the misorientation within the probed region caused by geometrically necessary dislocations, and depends on the orientation and the number of unpaired or geometrically necessary dislocations (GNDs) in the probed volume [2, 3]. By simulating Laue images with different GND slip systems, we model the set of slip systems that best fit the local lattice curvature and experimental Laue images.

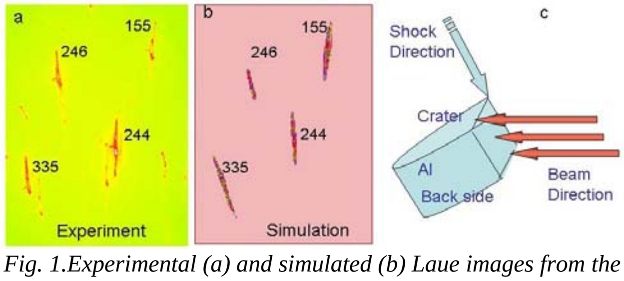

Fig. 1.Experimental (a) and simulated (b) Laue images from the crater region; scheme of the PXM experiment of the shock recovered Al sample (c).

The most interesting images are obtained from the so called "spallation" plane where X-ray tomography indicated intensive void formation. To better understand the reasons for such peculiar depth-integrated Laue images, 3D depth resolved measurements were performed (Fig. 2). These (differential aperture) measurements resolve the changes in the local orientation at different depths along the beam. They showed that in this region, alternating local lattice rotations take place. Much less streaking is observed in the upper half of the sample.

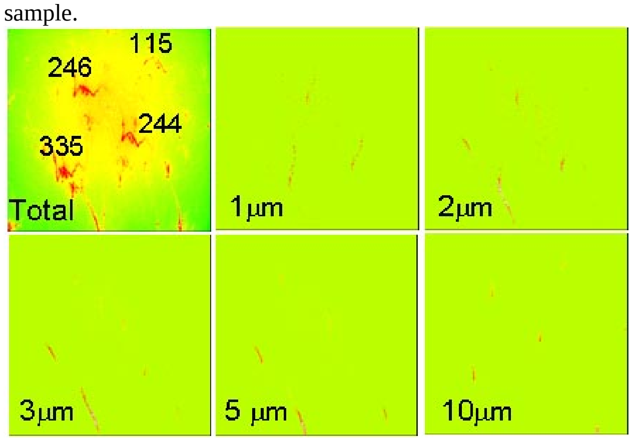

Fig. 2. Total Laue pattern and depth resolved images obtained with differential aperture technique (depth is shown in μm at each image).

Discussion

Microbeam-Laue diffraction reveals several distinct zones located at different depths under the shock front. Intensive mesoscale void formation is observed close to the center of the samples, which is accompanied by a peculiar and complicated shape of the Laue diffraction images.

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