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Materials Science/Condensed Matter Physics

Contrast Mechanisms in X-ray Microdiffraction Laue Images

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Introduction

Polychromatic x-ray microdiffraction is inherently sensitive to sub-grain orientations and average strains.[1] For nearly ideal polycrystalline grains, the local Laue pattern consists of sharp spots. However, the Laue image even from a local region can become smeared by particle size effects, strain gradients and by plastic deformation. We have analyzed Laue microdiffraction images with various contrast mechanisms that allow for a qualitative and/or quantitative measure of grain orientation and deformation. These maps illustrate the power of polychromatic x-ray microdiffraction to identify key materials properties such as the locally active slip system.

Methods and Materials

An iridium weld sample was mapped with a submicron-diameter x-ray microbeam in a grid of 80x80 points with a 3x3 μm pitch (240x240 μm^2). The x-ray microbeam was polychromatic and generated a complete Laue diffraction pattern for every grain penetrated by the beam. As the photoabsorption length of iridium is very short, the beam only penetrated about 5 μm into the sample and typically only the surface grain was probed at each point on the sample. Each Laue image was analyzed to determine the orientation of the grain and the average shape of the diffraction spots. A map of the grain orientation clearly defines the surface grain structure of the weld. The shapes of the spots were analyzed to determine the *direction* of smearing and the *magnitude* of the smearing. The direction of smearing is related to the dislocation system or systems locally activated.[2] The magnitude of the smearing along the major axis of the smearing is related to the number of excess dislocations. A quantitative theory of smearing and a study of how to deconvolute smearing arising from strain gradients from smearing due to deformation is under development.[3]

Results

A map of the dislocation magnitude is shown in Fig. 1a. Blue and black represent low deformation regions and pink and yellow represent high deformation regions. There are curious lines at about 45 degrees to the page that run through the largest grain in the image. These do not correlate to the scratches observed on the sample surface, (Fig. 1b), or to the orientation map and may result from dislocation cell structure generated during anisotropic cooling of the sample. Also notable are regions of low deformation that correlate to certain grain orientations. Analysis is underway to understand if these regions of low deformation arise primarily from the orientation of the individual grain probed, or due to the neighboring grain misorientation and morphology.

Discussion

X-ray microdiffraction Laue images of polycrystalline materials can be made with various contrast mechanisms that highlight particular features of the sample. For example in addition to the maps shown, we can highlight each of six elastic stress tensor elements, elastic stress gradients or a number of other important physical quantities. This ability to highlight qualitative and quantitative indicators of materials behavior is certain to have a major impact on our understanding of mesoscale dynamics.

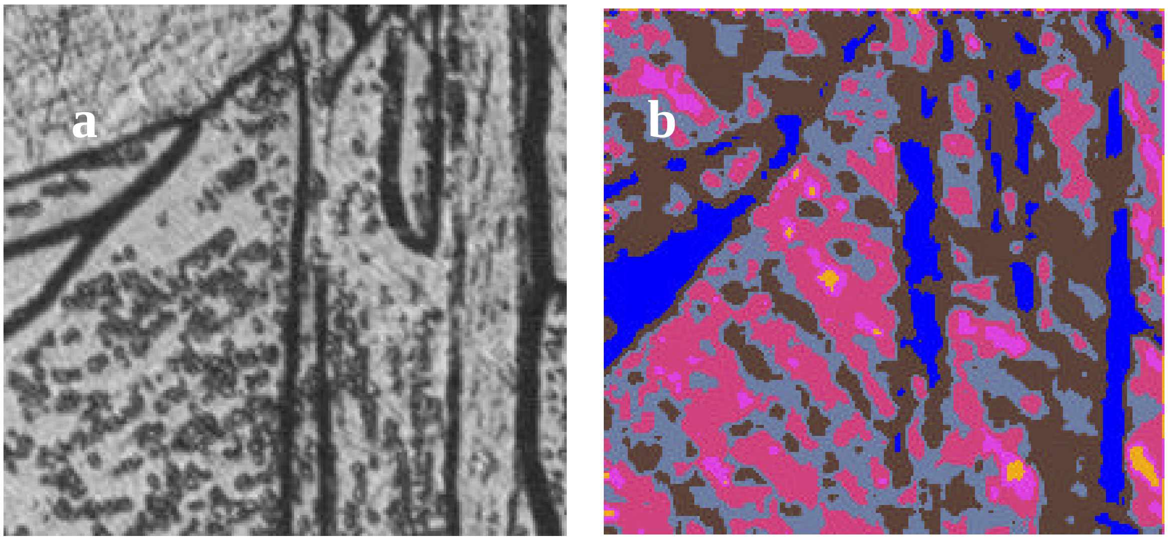

Fig. 1 a. Optical photomicrograph of a section of an iridium weld. b. False color image that uses Laue spot streaking magnitude as the contrast mechanism. This contrast is sensitive to the number of unpaired dislocations.

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