X-rays, microscopy, and rock and roll

Phil K. Cook[(1)], Can Yıldırım[(1,2)], Hugh Simons[(3)], Anders C. Jakobsen[(3)], Elise Dufour[(4)], Henning F. Poulsen[(3)], Carsten Detlefs[(1)]

(1) European Synchrotron Radiation Facility, 71, avenue des Martyrs, CS 40220, 38043 Grenoble, France
(2) Ocas Zwijnaarde, Technologiepark 935, 9052 Zwijnaarde, Belgium
(3) Danmarks Tekniske Universitet, Fysikvej, bygn. 311, 2800 Kgs. Lyngby, Denmark
(4) Archéozoologie, archéobotanique, UMR 7209 CNRS/MNHN, 55 rue Buffon, 75005, Paris, France

pcook@esrf.fr

A prototype full-field Hard X-ray Microscope (HXRM) has been constructed for the study of polycrystalline materials at ESRF ID06 [1]. Inspired by transmission electron microscopy, the instrument has been designed to perform dark-field imaging of individual grains using Bragg diffracted beams. A stack of beryllium compound refractive lenses is used in the diffracted beam to project a real-space image onto a camera positioned several meters downstream. Due to its limited field of view and angular acceptance, the lens effectively isolates the diffracting grain in real and reciprocal space. By coupling this X-ray optical system to a high-precision goniometer, the orientation of individual grains and variations within the grain can be imaged with a 100 nm real space resolution and 10 mrad angular resolution [2]. Strain within a grain can be measured with a resolution of 10^{-5}. Projections can be recorded in one second, and maps of strain or mosaicity can be recorded in a few hours. The instrument is applicable to a wide range of scientific fields, and has already been used for studies related to metal processing, semiconductors, and energy applications.

The instrument's capabilities will be illustrated with a case study of a biomineral structure. Otoliths ("ear stones") are aragonite concretions in the inner ear of vertebrates [3]. We present a new perspective from bulk analyses of crystalline bundles, revealing the relative orientations of the prismatic crystals as well as internal variations in orientation and strain.

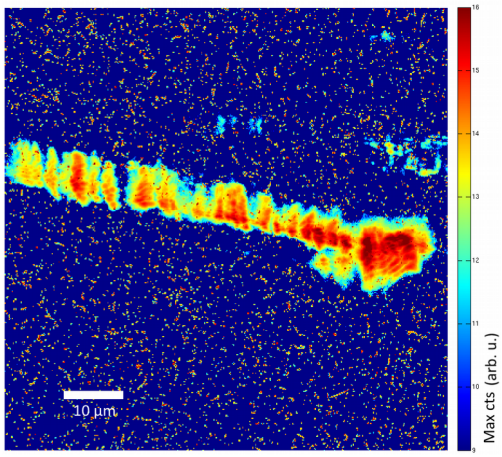

Figure 1. A dark-field image of an aragonite fibre from a fish otolith shows its growth from left to right in sequential layers, each composed of multiple crystalline units.

[1] H. Simons, A. King, W. Ludwig, C. Detlefs, W. Pantleon, S. Schmidt, F. Stöhr, I. Snigireva, A. Snigirev, H. F. Poulsen, Nat. Comm., 6 (2015), 6098.
[2] H. F. Poulsen, A. C. Jakobsen, H. Simons, S. R. Ahl, P. K. Cook and C. Detlefs, J. Appl Cryst., submitted.
[3] Y. Dauphin and E. Dufour, Micron, 39 (2008), 891.