Applications of Laue diffraction in rock deformation measurements

Camelia Stan[1], Nobumichi Tamura[1], Martin Kunz[1], Kai Chen[2,3,4] Catherine Dejoie[1,5] HR Wenk[4]

1. Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley CA 94720 USA
2. Center for Advancing Materials Performance from the Nanoscale (CAMP-Nano), State Key Laboratory for Mechanical Behavior of Materials, Xi'an Jiaotong University, Xi'an, Shaanxi 710049 China
3. National Center for Electron Microscopy, Lawrence Berkeley National Laboratory, Berkeley CA 94720 USA
4. Department of Earth and Planetary Sciences, UC Berkeley, Berkeley CA 94720 USA
5. European Synchrotron Radiation Facility, Grenoble, France

Material properties are linked to microstructure, e.g. grain size, grain orientation, phase distribution etc. Accurate crystallographic assignment of phases is critical for correctly assessing properties such as stress and strain in geological materials. In particular, α-quartz (P$3_1 21$ or P$3_2 21$) single crystals are prone to various types of twinning, which can lead to ambiguity in grain orientation assignment. Dauphine law twins are a common type of α-quartz twin, where domains with the same chirality intergrow but are distinguishable by a 60° rotation about the *c* axis of the trigonal unit cell. Proper assignment of single crystal orientation is crucial to accurately determining the stress tensor of the crystal, where misindexation can lead to large errors along the *ab* plane. At the Advanced Light Source beamline 12.3.2, we have developed energy dispersive diffraction (Laue) coupled with elemental identification using x-ray fluorescence (XRF) with 1-2 um beam size. We use this setup to generate 2D grain maps of polished natural quartz boudin samples from the Bastogne region of Belgium, with dimensions ranging from 160 x 100 um and 1 um step size to 4500 x 2600 um and 20 um step size. Macroscopically, these samples consist of alternating psammite (metamorphic fine-grained sandstone rock) and quartz. We determine quartz grain orientation in these samples unambiguously by using a statistical analysis of peak intensity as a function of indexed orientation in reflections with no harmonic overlap. We then calculate the strain tensor of each Laue pattern (~30,000 in the largest map) and find that all grains display elastic shortening perpendicular to the quartz vein walls, irrespective of grain direction. This indicates that boudinage forms through layer-parallel shortening, contrary to previously held beliefs. This study demonstrates how Laue diffraction can act as a fast, definitive and detailed tool in measurements of rock or mineral deformation.