Microstructure and Epitaxial Relationship of Chalcedony and Quartz in a Silica Agatoid Amygdule Studied by X-ray Micro-Diffraction

W.A. Caldwell[1], N. Tamura[1], H.A. Padmore[1], and J.R. Patel[1,2]
[1]Advanced Light Source, Ernest Orlando Lawrence Berkeley National Laboratory,
University of California, Berkeley, California 94720, USA
[2]SSRL/SLAC, Stanford University, P.O. Box 43459, Stanford CA 94309, USA

INTRODUCTION

Chalcedony is a fibrous, microcrystalline variety of silica (SiO_2) commonly found in geodes and amygdules. The inner regions of amygdules most often contain a sharp boundary separating the enveloping chalcedony from the central drusy (granular or equant) quartz. A number of disparities exist between chalcedony and granular quartz, most notably that chalcedony fibers are elongated (and grow) along the [100] direction, whereas the fastest growth direction in equant quartz is along [001]. This work consists of a structural study of a silica agatoid geode to determine if any epitaxial templating exists across the quartz/chalcedony interface. This information may shed light upon the uncertain paragenesis of chalcedony and amygdules [1,2].

EXPERIMENTAL

The sample is a silica agatoid amygdule found within the Grizzly Peak basalts of the Moraga Formation in the Berkeley Hills in Berkeley, CA. A petrographic thin section of the sample was made spanning the roughly 5 cm distance from the outermost section to the inner region which is filled with drusy quartz.

Initial characterization of the sample was performed with a petrographic microscope. White-beam Laue patterns in reflection mode at beamline 7.3.3 at the Advanced Light Source were taken and automatically indexed using a custom code (X-MAS) developed onsite. The X-ray microdiffraction end station on beamline 7.3.3 provided a high flux polychromatic (peak energy between 5-12 keV) beam with a size of approximately 1 x 1 micron. Its setup has been described

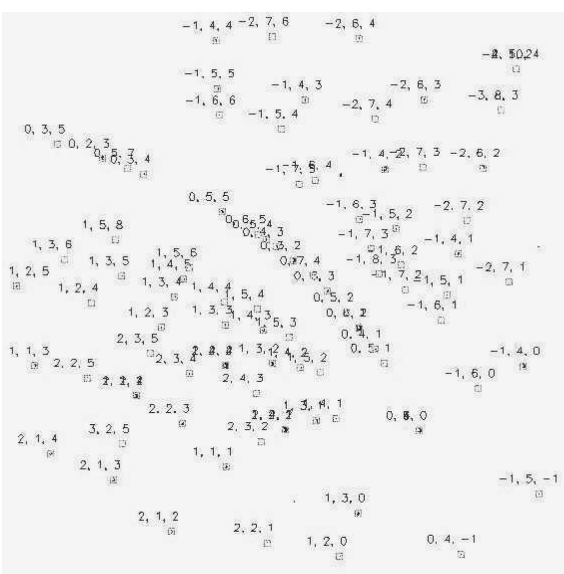

Figure 1. White-beam Laue pattern of quartz with Miller indices assigned.

elsewhere [3]. X-ray fluorescence measurements were taken simultaneous to the diffraction measurements to probe trace impurity concentrations. The diffraction patterns were analyzed to determine the orientation and deviatoric strain tensor of the chalcedony and quartz.

RESULTS

Numerous x-ray diffraction scans were made concentrating on the interesting area of transition from chalcedony to granular quartz. An indexed sample diffraction pattern taken from the granular quartz part of the sample is shown in Figure 1. Most diffraction patterns from the sample were, like that shown in Figure 1, free from signs of strain such as streaking of diffraction spots. However, at grain boundaries in particular the diffraction patterns became streaked. Deviatoric strain analysis of the diffraction patterns, which is sensitive to distortions in the shape of the unit cell, showed large regions (>50 μm) of low deviatoric strain interrupted by small areas (<10 μm) of high deviatoric strain. These high strain regions may be correlated with the grain structure, however, no major strain effects were noted in the chalcedony/equant quartz transition region.

The degree to which the [100] direction is aligned along the radial direction (pointing towards the center of the amygdule) is plotted in Figure 2. As seen in the left hand side of Figure 2, diffraction measurements confirmed the petrographic microscope observation that the chalcedony fibers are "length-fast" (elongated along the [100] direction) and radially oriented. Significantly, it appears that this orientation is preserved, at least initially, across the chalcedony/quartz transition. This opens up the possibility that some templating occurs during the initial stages of growth of the granular quartz upon the chalcedony.

X-ray fluorescence measurements were taken concurrent with the x-ray diffraction measurements to probe the trace impurity content of the sample. Unfortunately, the energy of Al fluorescence, which is a structurally important impurity, is below the detectable range of the detector. Other impurities, such as Ti and Fe, may reflect changes in the chemistry of the antecedent groundwater

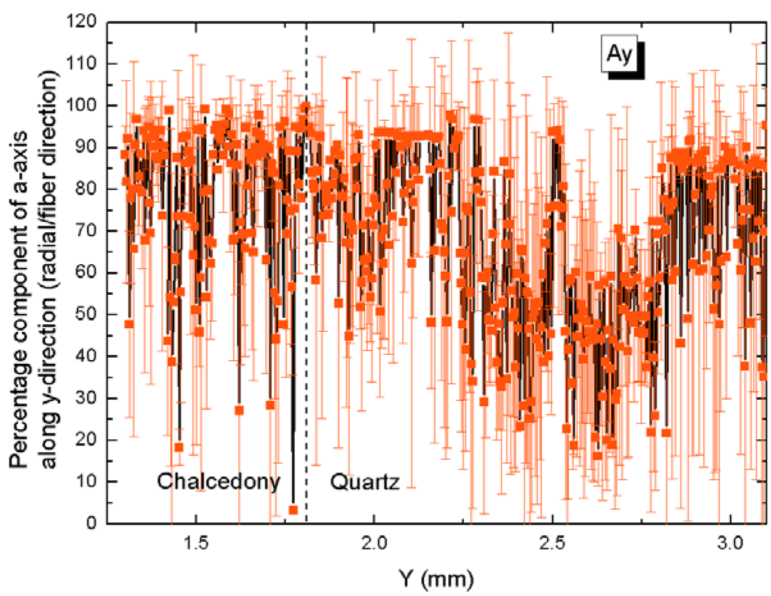

Figure 2. Percentage component of [100] projected along radial direction.

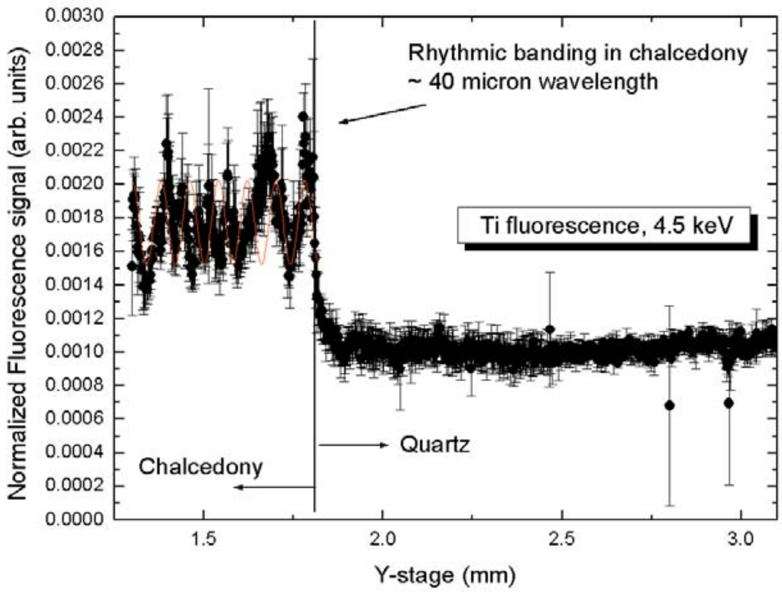

Figure 3. Fluorescence signal averaged over multiple passes across the sample.

that also transported the aqueous SiO_2. As shown in Figure 3, the titanium impurity content varies rhythmically in the chalcedony region before dropping markedly across the transition from chalcedony to quartz. This same trend was observed for iron as well as other impurities.

CONCLUSIONS/DISCUSSION

Except for small regions identified as grain boundaries, the measured deviatoric strain was low in the majority of the sample including the chalcedony/drusy border. The alignment of the [100] along the radial direction persists from the chalcedony to the granular quartz, indicating some degree of epitaxial templating across the boundary. Trace impurity levels which vary rhythmically in the chalcedony drop markedly across the boundary, suggesting a change in the chemistry of the parent solution. This last clue suggests that the structural change is due to a change in the chemistry of the parent solution and may agree with theories that maintain trace impurities are important in the development of chalcedony and agates.

ACKNOWLEDGMENTS

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Principal investigator: Wendel (Sander) Caldwell, Advanced Light Source, Ernest Orlando Lawrence Berkeley National Laboratory. Email: WACaldwell@lbl.gov. Telephone: 510-495-2233.