Transformation of SiO\textsubscript{2} to the amorphous state by shearing at high pressure

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ABSTRACT

A natural \(\alpha\)-quartz disc with flat surfaces perpendicular to (100) was sheared at 5 GPa in order to confirm that the sheared state at high pressure is not always the same as that obtained at high hydrostatic pressure. A transmission X-ray diffraction pattern taken from the sample that was sheared at high pressure revealed five broad halo rings; the pattern was taken about three months after the high-pressure experiment. The ratios of the interplanar spacing corresponding to the densest radius of the smallest ring to those of the other ones are 0.610, 0.514, 0.459, and 0.399, respectively. This set of rings does not appear from \(\alpha\)-quartz. These are approximately equal to those obtained from solids with space group \(Fd\bar{3}m\). A Raman spectroscopic study also showed the structural change due to shearing at high pressure. The spectrum appears neither from \(\alpha\)-quartz nor from coesite. These facts indicate, therefore, that the crystalline \(\alpha\)-quartz sample transformed to the amorphous state based on a structure consistent with \(Fd\bar{3}m\) space group.

INTRODUCTION

Structures sheared at high pressures sometimes remain the same at atmospheric pressure (Sakka 1975; Furuichi et al. 2001, 2002). On the other hand, we cannot deny the possibility that the solid state sheared at high pressure is not always the same as that at high hydrostatic pressure. Accordingly, we can expect to produce new industrial materials by shearing solids at high pressure. On the other hand, studies of solid structures sheared at high pressures impart fundamental knowledge to some field of physics and chemistry, because in the natural world there are cases where solids are sheared at high pressure. Their structures and state, however, have seldom been reported. Therefore, transformation of crystalline SiO\textsubscript{2}, one of the most popular ceramics, to the amorphous state by shearing at high pressure is the subject of this paper.

EXPERIMENTAL PROCEDURE

An \(\alpha\)-quartz plate, 1 mm thick, was cut off from a natural single crystal parallel to (100) using a diamond file to form the specimen shown in Figure 1. The specimen was put between two alumina rods tapered at one end (by \(\pi/4\) rad) and inserted into a magnesia octahedron as shown in Figure 2 (Lawlis et al. 1998). The pressure around the octahedron was then increased at the rate of 1 GPa per hour to 5 GPa. After maintaining this pressure for one hour, the pressure was lowered at the rate of 1 GPa per hour to the atmospheric pressure. While the pressure was increasing, the specimen was sheared in the [001] direction. After a lapse of about three months from the time of the shearing, a transmission X-ray diffraction pattern was obtained from a sheared specimen (target: Mo; filter: 0.1 mm thick Zr; collimator aperture: 1.0 mm; tube voltage: 40 kV; tube current: 40 mA; exposure time: 10 h; specimen to imaging plate distance: 50 mm) using an imaging plate. The shearing largely elongated the specimen only in the sheared direction ([001] direction), resulting in reduction of the thickness to about 70% of the initial value. The color of the sample changed from transparent and colorless to opaque milk white. Figure 3 shows a transmission X-ray diffraction pattern taken from the sheared specimen. We see five broad rings, although some are very faint and only a part of them can be seen on the printed page. Only the unusually long exposure time and the high sensitivity of the imaging plate made it possible...