

SHOCK OF DEFORMED QUARTZ

A. Gratz¹, J.A. Tyburczy², J. Christie¹, T.J. Ahrens³, and P. Pongratz⁴

1. Department of Earth and Space Sciences, UCLA, LA, CA USA 90024. 2. Department of Geology, Arizona State University, Tempe, AZ USA 85287. 3. Department of Geological and Space Sciences, California Institute of Technology, Pasadena, CA USA 94550. 4. Institut für Angewandte und Technische Physik, TU Wien, Karlsplatz 13, Vienna A-1060 Austria.

Deformed, synthetic quartz containing a dislocation density of $2.9 \pm 1.9 \times 10^8/\text{cm}^2$ and abundant bubbles and small inclusions was shocked to peak pressures of 12 and 24 GPa. The resultant material was inhomogeneously deformed and extremely fractured. The 12 GPa sample contained large regions lacking apparent shock deformation, suggesting that the original microstructure of a quartz target may be distinguished in low-stress shocks with minimal annealing.

Generally the same types of shock induced microstructures were induced by shock of deformed quartz as by shock of as-grown crystals. Glass-filled veins were abundant, especially at lower stresses, and contained angular fragments of quartz welded together. These fragments appear to have been forcibly removed from vein walls during emplacement of hot, fluid SiO₂ (T estimated as 3000-4000K). Microfaults formed on $\{10\bar{1}1\}/\{01\bar{1}1\}$ and $\{11\bar{2}2\}/\{1\bar{2}12\}$, inclined close to 45° to the shock propagation direction. Various curvilinear features occurred in groups, with contrast indicating moiré patterns, twins, and stacking faults or related structures; most were interpreted as fractures, possibly welded together with glass. Finally, regions containing shock lamellae sets were present (Fig. 1). Lamellae sets were uncommon at 12 GPa, but distributed every few microns at 24 GPa. Lamellae occurred in a spectrum of habits ranging from 35-1500Å in thickness, from 35Å upward in spacing, and from closely-packed parallel sets to networks of diverse orientations; some lamellae were not parallel-sided, but wedge-shaped with (0001) and $\{10\bar{1}3\}/\{01\bar{1}3\}$ edges. Thick lamellae (Fig. 1) were connected to glassy veins, and the wedge-shaped type generally narrowed away from veins; they also subdivided and merged along their length. Several lamellae terminated in dislocations.

Lamellae were dominantly basal at 12 GPa, and on $\{10\bar{1}2\}/\{01\bar{1}2\}$ at 24 GPa, lying with poles normal to the shock direction. Based on lack of observed shear offset and on habit, we propose that they are not shear features, but rather highly crystallographic glass-filled tensile fractures. Such fractures form upon release, nucleating on preexisting defects. In situ melting forms thin lamellae, which are subsequently widened by injection of hot SiO₂ (Fig. 2).

Vitrification was widespread, especially at 24 GPa, apparently more so than in shock of as-grown material. This suggests that change in index of refraction may not be an appropriate shock paleopiezometer. Lamellae spacing and thickness varied widely at any given stress level, without significant variation between stress levels, so these are also not valid criteria for shock paleopiezometry. Dislocation density was lowered in lamellae-containing and glassy areas, possibly removed by nucleation of lamellae. No high-pressure phases were observed.

Based on the complete set of observed features, it appears that shock deformation in quartz is primarily brittle-melt deformation, with an important role played by hot, fluid silica.

Acknowledgments: Research at Caltech supported under NGL-05-002-105.



Figure 1: Electron micrograph of shock lamellae formed at 12 GPa. Lamellae are dominantly basal; some are wedge-shaped. They are connected to a glassy vein (bright area, upper right), and generally thin away from it, in places reconnecting.

Figure 2: Diagram of possible genesis of connected glassy veins and lamellae. A large fracture and numerous small ones open up, propagating with dislocations at their tips. Hot fluid is forced into the larger fracture, forcibly removing material from the walls and widening the fine fractures at their trailing end. Lamellae recombine in places. The final result is numerous fine fractures (lamellae) and large fractures filled by a connected network of glass.

