Structural characterization of amorphized quartz resulting from diamond anvil cell and shock experiments

Christoph OTZEN (Albert-Ludwigs-Universität Freiburg, DE),
Giuseppe COCOMAZZI (Albert-Ludwigs-Universität Freiburg, DE)
Konstantin GLAZYRIN (Deutsches Elektronen-Synchrotron DESY, DE)
Falko LANGENHORST (Friedrich-Schiller-Universität Jena, DE)
Clemens PRESCHER (Albert-Ludwigs-Universität Freiburg, DE)

Abstract

Amorphous silica is among the most extensively studied disordered materials owing to its fundamental importance in a wide range of technical applications and scientific research fields. While vitreous silica is the archetypical glass produced by rapid quenching of an SiO_2 melt to ambient temperature, amorphous silica can also form through amorphization of quartz in the solid state at high pressures [1, 2, 3]. A particularly intriguing modification of amorphous silica is formed through the extreme conditions of meteorite impacts and shock experiments in the laboratory. For peak shock pressures ranging between approximately 10 to 35 GPa, planar deformation features are formed in quartz, which are sets of amorphous lamellae oriented parallel to low-index crystallographic planes [4, 5, 6]. For even higher peak shock pressures, quartz transforms completely into a so-called diaplectic glass.

Diaplectic glasses possess intriguing properties that are distinct from those of vitreous silica. For example, diaplectic glasses exhibit enhanced densities and refractive indices [4] and display a different annealing behavior [7]. Despite few investigations on the structures of diaplectic glasses [8], the structural characteristics leading to the distinct behavior of diaplectic glasses remain unclear to date.

Here, we investigated and compared the short-range order in the structures of amorphized quartz resulting from different experiments under extreme conditions – namely shock experiments on single crystals of quartz [5] and rapid compression experiments on powder samples of quartz at room temperature using the membrane-driven diamond anvil cell (mDAC). From the collected diffuse scattering of the amorphous silica, we calculated and analyzed structure factors and pair distribution functions. These indicate several differences in the short-range order of the amorphous silica samples. The structures of amorphized quartz are denser than the structure of vitreous silica. In agreement with previous results of shock-recovery experiments [4, 5], this compaction apparently decreases with increasing peak shock pressure, because the residual temperatures increase as a function of pressure. This is corroborated by DAC experiments at room temperature, which indicate that the density of amorphized quartz is increased. We can explain the differences also with the residual increased coordination of the silicon atoms in amorphized quartz after pressure decay. Detailed structural characteristics are provided by means of pair distribution functions, that may explain the distinct behavior of diaplectic glasses.

References

[1] Hemley et al. (1988) *Nature* 334, 52-54

[2] Kingma et al. (1993) *Science* 259, 666-669

[3] Otzen et al. (2023) *Nature Communications* 14, 606

[4] Engelhardt & Bertsch (1969) *Contributions to Mineralogy and Petrology* 20, 203-234

[5] Langenhorst & Deutsch (1994) *Earth and Planetary Science Letters* 125, 407-420

[6] Stöffler & Langenhorst (1994) *Meteoritics* 29, 155-181

[7] Höfler & Seifert (1984) *Earth and Planetary Science Letters* 67, 433-438

[8] Mashimo et al. (1980) *Physics and Chemistry of Minerals* 5, 367-377