# Shock-induced polymorphism in $SiO_2$ glass and alpha-quartz from *in situ* X-ray diffraction

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Constraining shock-induced transformations of major silicates and their kinetics is necessary to constrain planetary formation models of the terrestrial planets and to understand how meteorites and planetary surfaces have been affected by repetitive shocks. The recent coupling of ultrafast *in situ* X-ray diffraction (XRD) and shock compression techniques (gas guns and laser facilities) enables the direct investigation of transition mechanisms at short time-scales (from hundreds of picoseconds to hundreds of nanoseconds). In this study, we probed the structure at peak pressure of shocked $SiO_2$ glass (fused silica) and α-quartz single crystals by coupling ultrafast XRD to laser-driven shock compression at LCLS MEC end-station of SLAC XFEL facility (Stanford, USA; see Figure 1). The structure of shocked α-quartz was directly probed for the first time. This study also extends previous structural studies of shocked fused silica that we limited to 63 GPa.

We find that shocked fused silica forms a dense amorphous phase around 23 GPa. At 55 GPa, polycrystalline stishovite forms in few nanoseconds. These results present a disagreement with a recent laser-driven shock experiment that found stishovite crystallization above 18 GPa [1] but agree with a gas-gun experiment that places stishovite crystallization above 36 GPa and at least up to 63 GPa [2]. At 67 GPa and 80 GPa, we show that two stishovite-like polycrystalline phases with different densities coexist with the highest density phase dominating at 80 GPa. Above ~100 GPa, $SiO_2$ melts along the Hugoniot of fused-silica as XRD pattern present two diffuse peak typical of 6-fold Si-O coordinated amorphous silicates.

Due to its crystalline structure, α-quartz crystals shocked along the [001] direction preserve a crystalline structure at 28 GPa. Above 60-70 GPa and up to the equilibrium melting line, polycrystalline stishovite-like $SiO_2$ forms and coexists with increasing amounts of seifertite (α-$PbO_2$-type $SiO_2$).

Our results provide strong insights on the phase transformation mechanisms and kinetics in shocked silicates. We will compare them to theoretical investigations and experimental measurements obtained under static compression, and we will discuss their implications in shock metamorphism and planetary science.

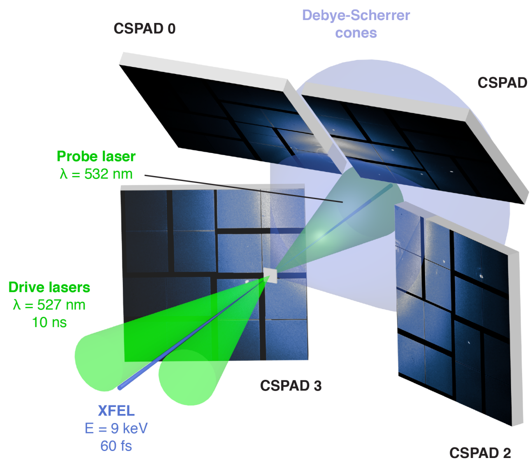


*Figure 1*. Experimental setup. The 60 fs XFEL pulse samples the structure of laser-shocked $SiO_2$ quasi-instantaneaously. Four Cornell-SLAC Pixel Array detectors are positioned around the XFEL axis to collect the diffracted signal.

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