The Role of Quenching Pressure on Shock-Induced Phase Transformations in Silica Glass

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Research Question

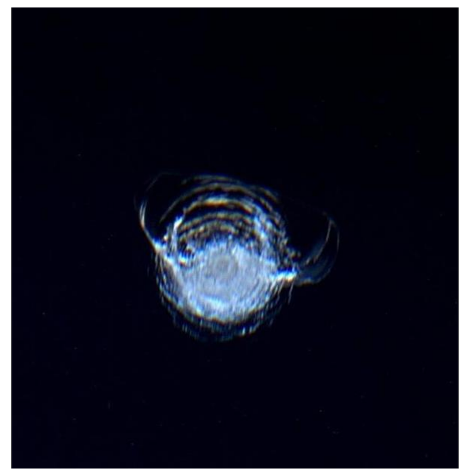
Does quenching pressure influence the shock-compression behavior of silica glass?

Research Relevance

By investigating the effect quenching pressure may have on the compressibility of silica glass, we could potentially uncover new techniques for increasing the resilience of glass surfaces in space applications.

[1]

Cupola Module aboard ISS



[2]

Space Debris Impacts *Cupola* Module's Fused-silica Windows

Methodology

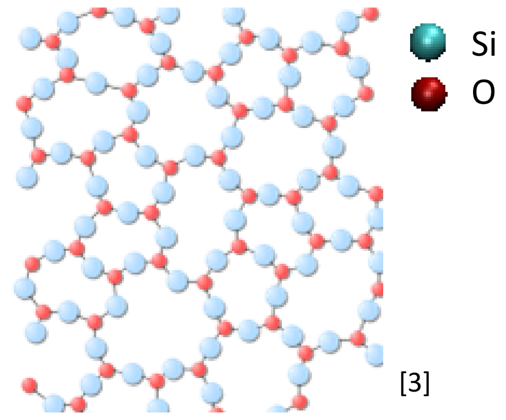
We used LAMMPS, a high performance molecular dynamics simulator, in conjunction with ASU's HPC Agave cluster to answer our research question.

Molten silica systems were quenched to 300K while under 0.1, 10, 30, and 50 GPa of pressure. Then, each of these quenched systems were shocked at 30, 40, 60, and 70 GPa, producing a total of 16 shocked systems. In order to provide a confidence interval for our results, an additional 3 sets of the 16 shocked systems were produced.

By comparing the Shock Hugoniot plots and structures of these shocked systems, we can deduce whether quenching pressure does or does not influence the shock-compression behavior of silica glass.

Methodology

Under large shock pressures (35+ GPa), a dense tetragonal form of silica called stishovite has been found to form in previous studies. Therefore, we examined our shocked systems for crystallization and noted under what conditions crystallization occurred.



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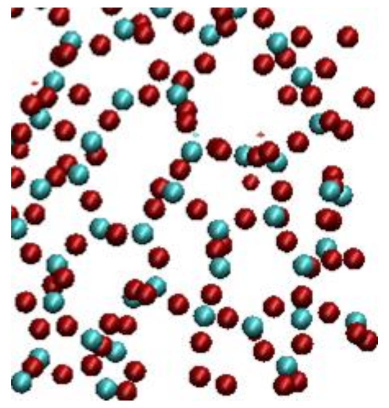
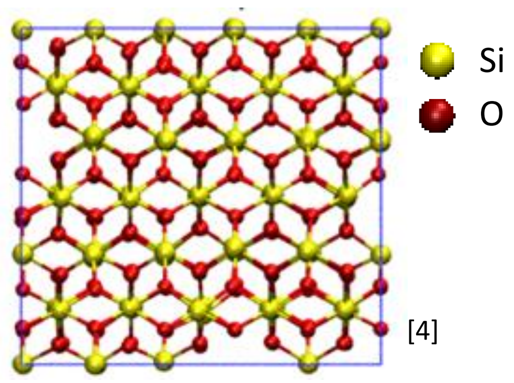


(Left) Figure of Amorphous Silica

(Right) LAMMPS Generated Amorphous Silica



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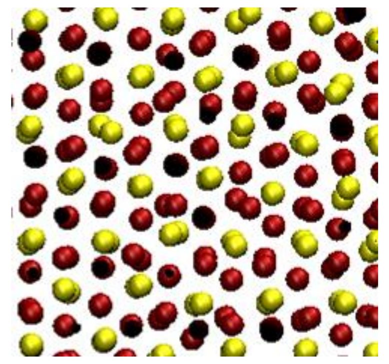
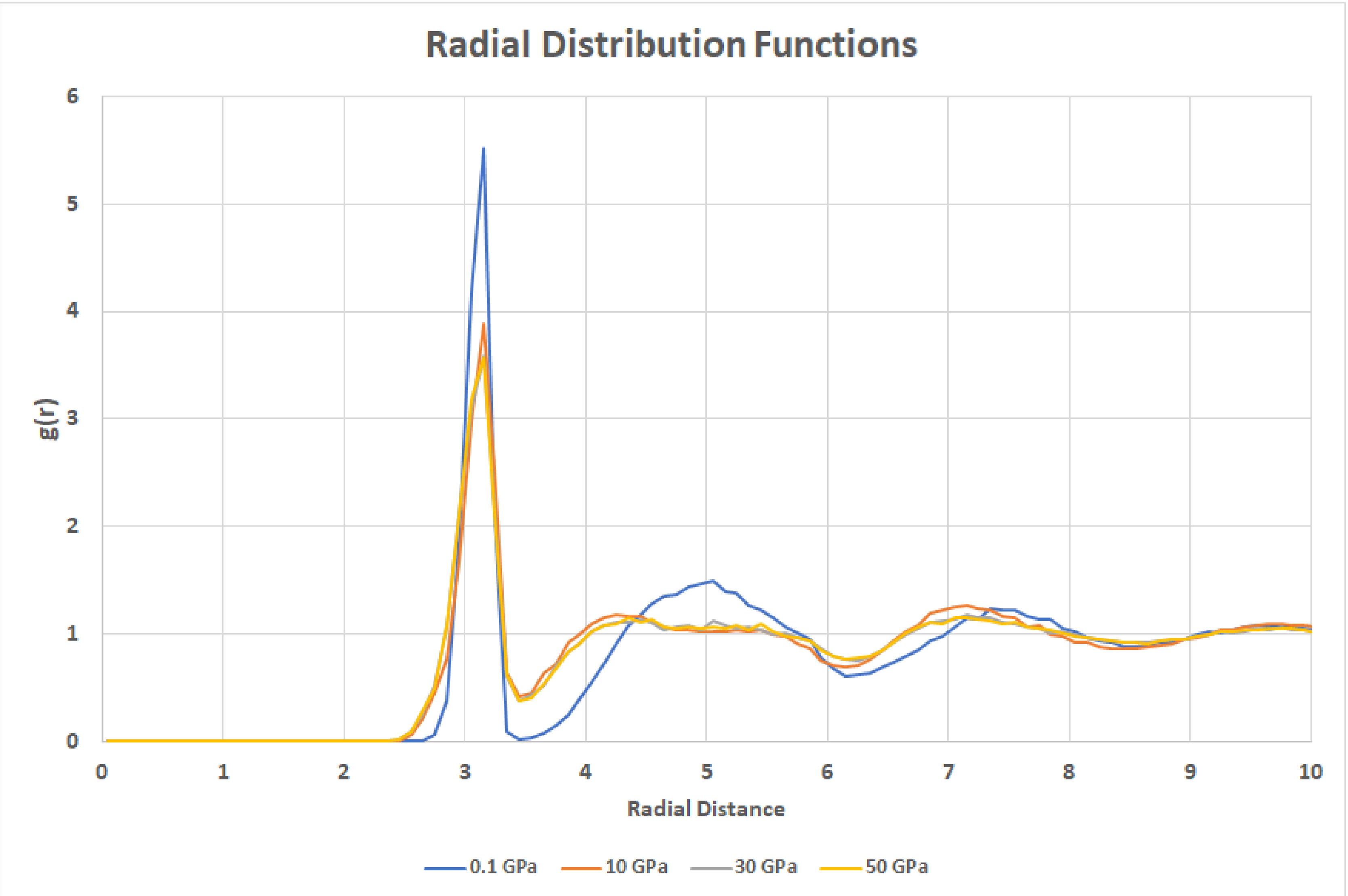


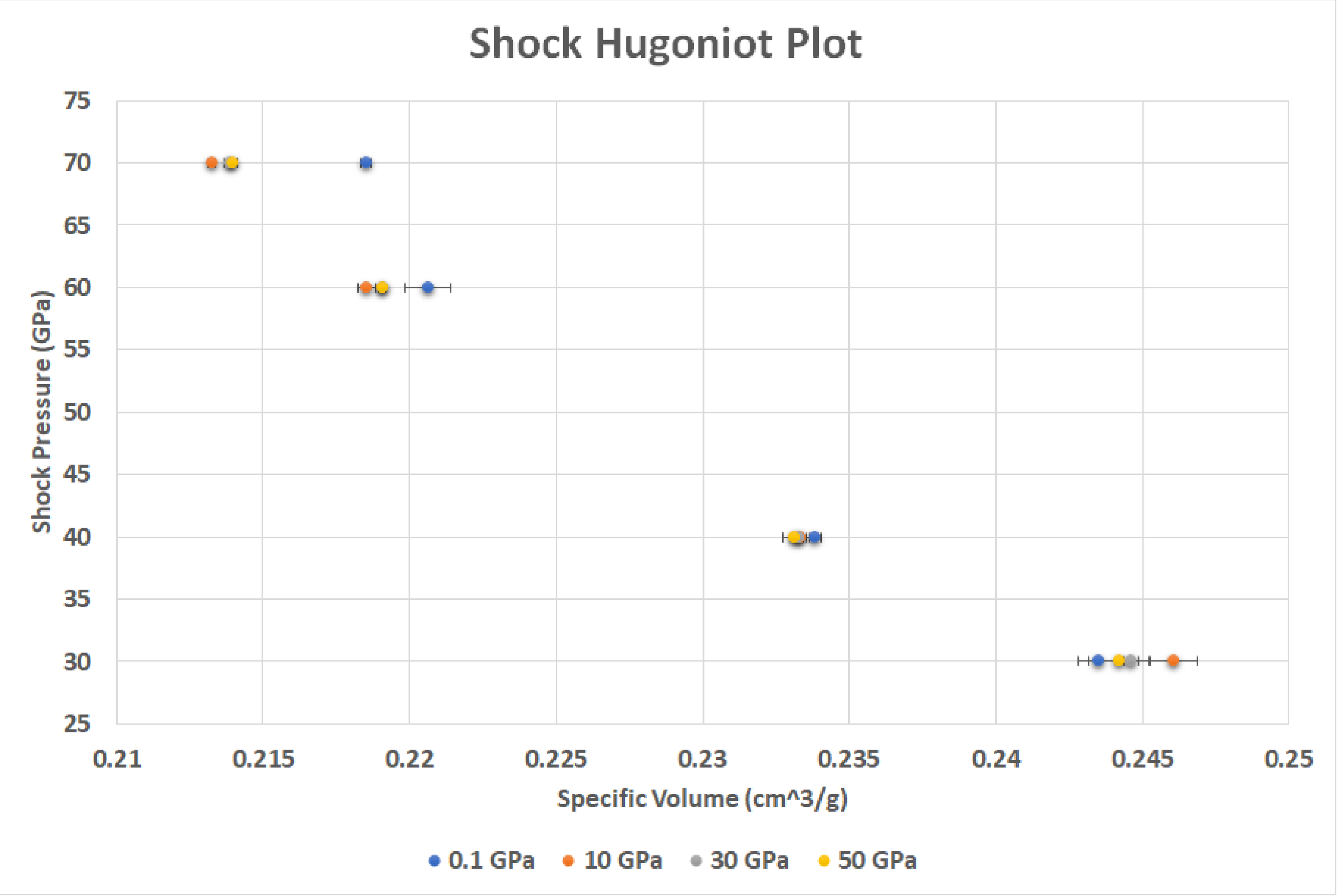
(Left) Figure of Stishovite

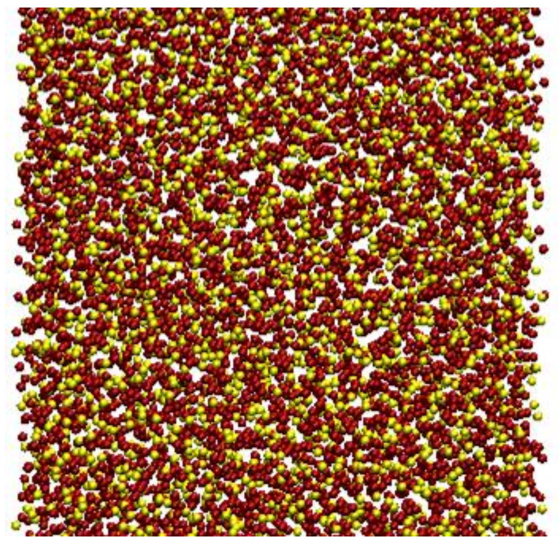
(Right) LAMMPS Generated Shocked Silica at 60 GPa

Results

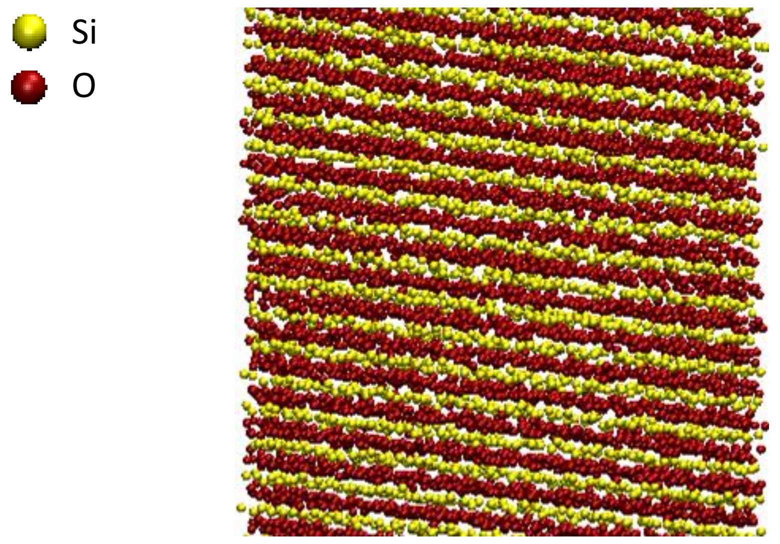


Results





Amorphous Silica



Crystallized Silica

Conclusions

- Systems quenched at higher pressures exhibit more amorphousness, correlating to flatter RDFs
- For high shock pressures, specific volume of 0.1 GPa quenched systems much larger than 10, 30, and 50 GPa
- Crystallization occurred only for systems quenched at 0.1 GPa and shocked at 60 GPa
- Quenching pressure does influence the shock-compression behavior of silica glass

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Works Cited

[1] "Exterior of Cupola." *NASA*, 2011, spaceflight.nasa.gov/gallery/images/station/crew-28/html/iss028e048571.html.

[2] Peake, Tim. "Impact Chip." *European Space Agency*, 5 Dec. 2016, www.esa.int/ESA_Multimedia/Images/2016/05/Impact_chip.

[3] Sedano, Guillermo. "Silica." *Silica - Molecule of the Month November 2013*, 2013, www.chm.bris.ac.uk/motm/silica/silicah.htm.

[4] Misawa, Masaaki, et al. "Picosecond Amorphization of SiO2 Stishovite under Tension." *Science Advances*, vol. 3, no. 5, 12 May 2017, doi:10.1126/sciadv.1602339.

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