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Shock compression of silica gel as the analog experiments of hydrous comet and meteorite

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The studies for structural changes of hydrous silica materials by shock compression are important to obtain the information for compression behaviors of comet and meteorite made of silicate material, ice and hydroxyl on the impact event.

In this study, TEOS-derived synthetic silica gels for the analog material of hydrous amorphous silica minerals were compressed under shock pressures of 11, 13, 17, 21, 27, and 31 GPa using a single-stage propellant gun. All recovered samples have been investigated by XRD measurements, Raman and IR spectroscopies, in order to elucidate the shock compression behavior of silica gel. Pressure variation of first sharp diffraction peak (FSDP) positions of samples was estimated from measured XRD patterns. FSDP position of as-prepared sample was smaller than silica glass. It indicates that medium range structure of silica gel, i.e. ring structure of SiO4 tetrahedra, is smaller than that of silica glass. FSDP positions showed negative shift with increasing pressure and approached that of silica glass at 31 GPa. It suggests that medium range structure of silica gel approached to silica glass by shock compression.

Raman spectrum of as-prepared sample showed an intense D1 band at 480 cm-1 and a broad band at around 450 cm-1. The former is attributed to the oxygen-breathing mode of the four-membered ring of SiO4 tetrahedra and the latter to the symmetrical Si-O-Si stretching mode. The presence of strong D1 band of as-prepared sample indicates that the sample might contain considerable amount of four-membered rings in the structure. Shocked sample showed that the broad band around 450 cm-1 became prominent above 21 GPa, whereas D1 band became much less intense. These indicate that medium range structure of shocked sample above 21 GPa approached to that of silica glass. Furthermore, IR spectrum of shocked silica gel at 21 GPa indicates that the center part of sample showed development of vitrification as compared with the extremity part of the sample.

As-prepared sample contained a large quantity of molecular water and silanols. Both the Raman and infrared spectra of shocked silica gels showed decrease of water molecule with increasing pressure. Raman spectrum of as-prepared sample contained the band of surface silanol as Q2 and Q3 species in the region of 900-980 cm-1. Above 21 GPa, weak tail around 900 cm-1 which attributed to Q2 band disappeared, resulting in some germinal silanol was dehydrated and condensed by shock compressions. Moreover, Raman spectra contained prominent new peak around 3600 cm-1 above 21 GPa. It may indicate that mutually hydrogens bonded silanols were present in the surface of sample. At 31 GPa, the adsorbed molecular water at the surface of sample may be completely released, whereas some silanol remained even at this pressure. This study reveals that silanole could remain by changing its style even at high shock pressure > 21 GPa, whereas water molecules are released easily.

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