Formation process of high-pressure silica polymorphs in lunar meteorites of the NWA 773 clan

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Introduction: Asteroid and meteorite collisions lead to formation of impact crater, crustal breccia and thick regolith on then Moon, and also contribute to revolution of the Earth-Moon system, e.g. Giant Impact and the late heavy bombardments. Although lunar meteorites and Apollo samples have experienced such impact events causing brecciation, ejection from the surface and/or formation of immense basin, they had been considered to contain few high-pressure minerals because of the volatilization during collision in the high vacuum. However, recent investigations of lunar meteorites and Apollo samples discovered high-pressure silica polymorphs in Asuka-881757 [1], Northwest Africa (NWA) 4734 [2] and Apollo 15299 samples [3], providing new constraint on the shock pressures and temperatures. In this study, we discovered high-pressure phases of silica for the first time from lunar meteorite NWA 773 clan using microanalyses and constrain the shock-pressure and post-temperature in order to interpret the impact history on the lunar surface.

Samples and Methods: We investigated NWA 773 clan including NWA 2727, 2977 and 6950; NWA 2977 and 6950 are classified as gabbroic lunar meteorites which consist of olivine, clinopyroxene and plagioclase. NWA 2727 is a brecciated meteorite mainly consists of the gabbroic clasts similar to NWA 2977 and 6950 lithologies and the basaltic clasts with clinopyroxene phenocrysts and fine feldspar-pyroxene-silica-rich groundmass. In NWA 2727, fine to coarse grained lithic minerals fill the interstices between the gabbroic and basaltic clasts as breccia matrix. Silica polymorphs of these lunar meteorites were found by micro-Raman spectroscopy, transmission and scanning electron microscopies and synchrotron X-ray diffraction (SR-XRD) analysis.

Result and Discussion: Silica polymorphs occur in the basaltic clast and the breccia matrix of NWA 2727, but almost absent in NWA 2977 and 6950. Raman spectroscopy and electron microscopies of NWA 2727 show isolated coarse-grained tridymite and cristobalite (50–500 μm in diameter) and fine-grained quartz (10–30 μm in diameter) in the basaltic clasts. However, almost no signal of high-pressure silica phase was detected in Raman spectroscopy, selected area electron diffraction (SAED) analysis and SR-XRD measurement of the basaltic silica grains.

A large amount of fine silica grains (10–20 μm) is also observed in the breccia matrix of NWA 2727 under SEM images, and is composed of coesite and stishovite in rims of the grain and silica glass and quartz in the interior by Raman spectroscopy. The excavated brecciated silica grains, extracted as a square cube with 10 μm per side with a focused ion beam system, could be identified as nanocrystalline aggregates of few-nm-sized grain under TEM observation, and SAED and SR-XRD patterns of the aggregates well correspond to mixtures of coesite, stishovite and quartz. Therefore, nanocrystalline aggregates of quartz and silica glass grains are likely to have been precursors of coesite and stishovite in the breccia matrix. Based on the present and previous data [4], NWA 2727 have experienced an equilibrium shock-pressure of at least >8 GPa. Since such nanocrystalline aggregates are distributed only in the breccia matrix, shock-brecciation on the Moon may be closely related to formation of the coesite and stishovite.

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