SHOCK-INDUCED MELTING AND HIGH-PRESSURE POLYMORPHS IN LUNAR BASALTIC METEORITES

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Introduction: Since the Moon was born, countless meteoroids have collided on the moon. Lunar meteorites and lunar return samples record the meteoroid impacts occurred on the moon. The high-pressure polymorphs occurring in these samples are the intriguing clues for clarifying the impact events on the lunar surface, because we can constrain several physical parameters (e.g., shock pressure, duration of shock pulse) for the meteoroid impacts using the kinetics of high-pressure polymorphs [e.g., 1, 2, 3]. We have investigated only a few lunar meteorites and return samples about the high-pressure polymorphs so far. Hence, we initiated to conduct systematic investigation about the shock-induced melting and high-pressure polymorphs in the lunar mare basaltic samples NWA 032, NWA 479, NWA 2727, NWA 2977, and NWA 4898 using FE-SEM, micro-Raman spectroscopy, EMPA, and FIB-TEM techniques to obtain the clues for clarifying the impact events occurred on the moon.

Results and Discussion: NWA 032 and NWA 479 had a basaltic lithology. Olivine, Ca-pyroxene, and low-Ca pyroxene occurred as phenocrysts. The matrix was filled with spherulitic textures consisting of plagioclase and Ca-pyroxene. Several shock-melt veins and melt-pockets occurred both in NWA 032 and NWA 479. Olivine grains next to the shock-met veins have transformed into ringwoodite in NWA 032. Olivine grains entrained in the shock-melt veins of NWA 479 have dissociated into bridgmanite (vitrified) + (Mg,Fe)O. The estimated shock pressures for NWA 032 and NWA 479 are ~13 GPa and ~23 GPa at least, respectively.

NWA 4898 also had a basaltic lithology. Olivine occurred as phenocrysts, and the matrix consisted mainly of Ca-pyroxene and plagioclase. Shock-melt veins cut the basaltic lithology. The shock-melt veins entrained a trace amount of silica minerals. The silica minerals in the shock-melt veins were stishovite and silica-glass. Ca-pyroxene next to the shock-melt veins has dissociated into ahrensite, pyroxene-glass, and (probably) silicate titanite. The estimated shock pressure for NWA 4898 is ~9 GPa at least.

NWA 2977 showed a gabbroic lithology and consisted mainly of olivine, low-Ca pyroxene, Ca-pyroxene, and plagioclase. Olivine grains entrained in the shock-melt veins have transformed into ringwoodite. The estimated shock pressure for NWA 2977 is ~16 GPa at least.

Two third of NWA 2727 had a breccia lithology and the other had a gabbroic lithology. The gabbroic lithology consisted mainly of olivine, low-Ca pyroxene, Ca-pyroxene, and plagioclase. Shock-melt veins and melt-pockets occurred both in the breccia and gabbroic lithologies. The breccia lithology included silica minerals besides the fragments of the gabbroic lithology. Silica minerals entrained in the shock-melt veins or melt-pockets have transformed into coesite. The estimated shock pressure for NWA 2727 is ~3 GPa at least.

We found shock-induced melting (shock-melt veins and melt-pockets) and high-pressure polymorphs therein in all investigated lunar samples. Most lunar return samples are brecciated, which is suggestive of heavy meteoroid impacts. Our present systematic investigations revealed that most lunar mare basalts also have experienced a heavy meteoroids impact. We plan to estimate the duration of shock pulse using the kinetics of high-pressure polymorphs identified in the present study. We also found minerals suitable for the radio-isotope dating in the shock-induced melting textures and host rocks. As a next step, we will conduct the radio-isotope dating using the same samples studied here in feature to evaluate the relevance between the radio-isotope ages and shock features (shock pressure, temperature, duration of shock pulse, etc.).

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