Phase boundary and kinetics of moganite-coesite phase transition at high-pressure and high-temperature: implications for an impact event and trace of water on the Moon

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Moganite is a monoclinic SiO_2 mineral that forms by precipitation from alkaline fluid under high-pressure condition. Recently, moganite was first discovered in a lunar meteorite NWA 2727, supporting water activity on the surface of the Moon (Kayama et al., 2018). Moganite in NWA 2727 always coexists with coesite, a high-pressure polymorph of SiO_2. This fact suggests that a heavy impact event occurred on the host site of NWA 2727 on the Moon, resulting in high-pressure phase transition of moganite to coesite. On the other hand, other silica polymorphs such as quartz, tridymite and cristobalite in NWA 2727 have not been transformed into coesite. Although moganite seems to change into coesite more easily than other silica polymorphs, the phase boundary and kinetics of the moganite-coesite phase transition remain unknown. In this study, we performed high-pressure and high-temperature experiments on terrestrial moganite up to 8 GPa and 500 ˚C to determine the phase boundary and kinetics of the moganite-coesite phase transition.

In all experiments, natural terrestrial moganite (Gran Canaria, Spain) and synthetic quartz powders were loaded separately in two different sample rooms in a high-pressure cell and kept at the same pressure and temperature conditions. The samples were first compressed to the target press load at ambient temperature and then heated to the target temperature. The high-pressure and -temperature experiments and X-ray diffraction (XRD) measurements were conducted at the beamline AR-NE5C of the Photon Factory at the High Energy Accelerator Research Organization (KEK).

As a result of time-resolved XRD analysis, it was revealed that moganite transformed into coesite more rapidly than quartz under the conditions of ˜5 GPa and 425 ˚C and ˜8 GPa and 250 ˚C. The different kinetics between moganite and quartz would be due to a similar crystal structure between moganite and coesite with a common four-membered rings structure (Murashov and Svishchev 1998) and/or relatively high water content of moganite (1-5 wt% in general) compared with quartz, both of which reduce the activation energy of the phase transition from moganite into coesite. Our result demonstrated that the different phase transition kinetics of silica polymorphs to coesite can explain the contrasting coexistence relationship of silica minerals in NWA 2727: in a short duration of an impact event, only moganite was able to transform into coesite with a relatively high phase transition speed. In addition, this fact revealed here supports the possibility that moganite in NWA 2727 is indigenous to the Moon.

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