Mineralogical study of quartz and tridymite in cumulate eucrites

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Introduction:Silica mineral is one of the most important rock-forming minerals on the Earth. It has 23 or more polymorphs under various temperature and pressure conditions [Sosman, 1965]. There are not so many silica minerals in meteorites, but some report silica minerals such as α-quartz, tridymite, cristobalite etc. However, in many cases, they are simply described as “silica minerals” alone and their specific mineral species are rarely identified. Tridymite is the most common silica mineral in meteorites. Tridymite has two crystal systems, monoclinic and orthorhombic. Both of them are hexagonal at high temperature, but monoclinic is known to undergo some different orthorhombic systems upon cooling. Their transition processes and relations of crystal structures are very complicated. Most tridymite in meteorites are monoclinic [Graetsch and Florke, 1991]. Although silica minerals have various polymorphs, they are not fully discussed using polymorphic relations in meteorite science. Therefore, in this study, we focus on silica minerals in three cumulate eucrites and discuss their formation conditions and inversion rate of silica minerals considering their cooling histories.
Sample and Method:We analyzed Moore County, Moama, and Y980433. We first located positions of silica minerals using optical microscopy, SEM, and X-ray mapping by EPMA. After that, silica minerals were identified by EBSD patterns and micro-Raman spectroscopy.
Result and Discussion:Tridymite is the only silica mineral in Moore County and Moama. In contrast, Y980433 contains tridymite and quartz. All tridymite in Moore County is monolclinic and larger (~3 mm) than those in other samples. Moore County is estimated to be once cooled from 990 C to 730 C at 0.00016 C/yr and later it was heated up to 930 C and then cooled down to 730 C at a much faster rate of 0.3 C/yr [Miyamoto et al., 1992]. Tridymite in Moore County is larger than other meteorites because initial cooling rate was slower than other meteorites. In Moama, the maximum size of tridymite is about 0.5 mm, but most are less than 0.1 mm. Our observation reveals that most tridymite grains have lamellar texture. Its host is monoclinic but lamella is orthorhombic. Moama is known to have been slowly cooled at 0.0004 ^{o}C/yr [Harlow et al., 1979], which is slightly faster than Moore County. There is a possibility that orthorhombic tridymite lamella in Moama formed by partial inversion from monoclinic to orthorhombic, but it is not clear. Tridymite in Y980433 is euhedral. According to EBSD patterns, it has two different types of crystal structures, monoclinic and hexagonal, but Raman spectra showed that they are all monoclinic. We considered that these two types of EBSD patterns are the result of twinned monoclinic tridymite [Tagai et al., 1977] or fitting error by the analysis software. Y980443 has quartz at the rim of melt vein or grain boundary of pyroxene and plagioclase. We infer from their anhedral shapes that quartz crystallized by a different process from tridymite, for example impact metamorphism. Because plagioclase is partially transformed to maskelynite, melt vein was considered to be occurred by impact.
Conclusion:It is considered that tridymite in cumulate eucrites is the late-crystallization phase, and it is interesting that tridymite is present in different crystal systems probably due to different thermal histories. The lamellar texture of tridymite in Moama may be due to partial inversion of different tridymite crystal structures caused by relatively fast cooling. Unshocked nature of Moama rules out shock metamorphism. Because most quartz grains in Y980433 are anhedral, they would be a product of crystallization from impact melt. It is necessary to elucidate detailed crystal structures of meteoritic silica phases (especially tridymtie) to further understand complicated polymorphic association of silica minerals in light of thermal history of meteorites.

Keywords: silica minerals, eucrite, cooling rate, inversion, tridymite

