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Insights from silica minerals on chondrule formation, metamorphism and impact processing of EH chondrites

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Unusual sulfide minerals, Si dissolved in metal and the FeO-poor compositions of mafic silicates attest to the formation and metamorphism of enstatite chondrites (ECs) at low oxygen fugacities. Because of these unusual conditions, some metamorphic reactions in ECs are different from those of ordinary and carbonaceous chondrites [1]. Furthermore, shock events have affected the thermal histories of ECs [2]. Therefore, it has been difficult to infer metamorphic sequences for the ECs and to distinguish effects of nebular processes from thermal and shock metamorphism. In this study we focus on textures and phases of silica to distinguish nebular vs. metamorphic crystallization events in three EH chondrites.

Our main results are from three polished thin sections of ALHA81189 (EH3), ALH 84170 (EH3) and St. Marks (EH5). Other enstatite chondrites were used for comparison. Thin sections were examined using petrographic microscopes. Mineral analyses, elemental maps, and back-scattered electron images were collected using a JEOL JXA-8900 electron microprobe at Waseda University. Silica polymorphs were identified by Raman spectroscopy using a Jobin Yvon LabRam 300 Raman micro-spectrometer [Horiba, Ltd.] at Waseda.

Chondrule textures and the clastic matrix characteristic of type 3 enstatite chondrites [3] are easily identified in ALHA81189 and ALH 84170. These rocks contain coarse olivine. Silica is also present, often as fine-grained rims around chondrules. The presence of olivine with silica is evidence of the unequilibrated state of these two samples. Disequilibrium is also indicated by the wide range in Mg/(Mg+Fe) of pyroxene and olivine. Some of our Raman spectra from silica in the two samples are ambiguous, perhaps due to fine grain sizes, poor crystallinity, or the presence of some glass. Nonetheless, Raman spectra indicate that cristobalite is present in both samples. No other silica polymorph was identified in ALHA81189. Quartz was identified in ALH 84170 and some ambiguous spectra suggest tridymite. Tridymite and quartz, as well as cristobalite and glass, were identified in ALH 84170 by Kimura et al [4], who also used Raman spectroscopy.

In contrast to the two EH3 chondrites, original chondrule/matrix textures have been recrystallized in St. Marks, though some chondrules can still be recognized. No olivine was identified in St. Marks, and almost all of the pyroxene is Fe-poor. Silica occurs as coarse equant crystals. Raman spectra from silica in St. Marks are clear and all of our spectra indicate quartz, consistent with [4].

With the exception of some relict chondrule textures and rare Fe-rich pyroxene, St. Marks has been thoroughly recrystallized during parent body metamorphism. Although we cannot be certain that peak metamorphic temperatures were in the quartz stability field, the universal occurrence of silica as quartz in St. Marks suggests that this is likely.

Only one silica polymorph (cristobalite) was identified in ALHA81189; based on this observation alone, ALHA81189 could be interpreted as an equilibrated chondrite. However, as discussed above, other parameters indicate the unequilibrated condition of this sample. The abundance of cristobalite is due to high temperatures and rapid cooling associated with chondrule formation.

Several silica polymorphs are present in ALH 84170, indicating disequilibrium. Two interpretations are possible. (1) Quartz formed in situ during metamorphism of ALH 84170, and cristobalite, tridymite and silica glass are relict phases from chondrule formation. (2) Quartz in ALH 84170 formed during metamorphism of a previously existing rock and was mixed with the other silica phases during impact processing.

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