

Formation process of a multi-layered chondrule rim and relationship of fine-grained rim and matrix in two LL chondrites

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Chondrules in primitive chondrites are commonly surrounded by two types of rims: coarse-grained rims and fine-grained rims. Many studies of CM chondrites suggest that fine-grained rims are formed by the accretion of dust onto chondrules in the solar nebula (e.g., Metzler et al., 1992). However, recent studies of CV chondrites show that fine-grained rims formed by parent-body process (e.g., Tomeoka and Ohnishi, 2015). No conclusions are obtained so far as to whether the rims were formed by the parent body process or the nebular process.

In this study, to uncover the origin of fine-grained rims and the relationship of fine-grained rim and matrix material in ordinary chondrites, we investigated mineralogy and chemical composition of coarse-grained rims, fine-grained rims and matrix material in Y-75273 (LL3.2) and Y-74660 (LL3.0) using an optical microscope, FE-SEM, and FE-EPMA.

Many chondrules in Y 75273 are surrounded by fine-grained rims. Among them, we found a multi-layered chondrule rim. The rim consists of five layers made up with four inner coarse-grained rims (1-4th layer) and one outermost fine-grained rim (5th layer). Mineral combination of 1-4th layer is similar, but relative mineral abundance, grain size, and chemical composition of the minerals differ among the four rims. The boundaries between the 3rd and 4th layer, between the 4th and 5th layer are distinct and smooth (no topographic depressions).

Defocused (10 μ m diameter) electron beam analysis of each layer shows compositional variation in individual rims: in a Si-Mg-Fe ternary diagram, the 2nd layer data distribute close to the solar abundance and the 1st- and 2nd- layer data make a trend from solar toward the Si-apex suggestive of addition of Si-rich material such as silicate glass, while the 3rd and 4th layer data distribute from solar to the Fe-apex indicative of addition of Fe-rich material such as Fe sulfide and Fe-Ni metal. On the other hand, the 5th-layer data fall on the different compositional field in Fe-rich areas relative to solar. The compositional field of the 5th layer overlaps those of the single rims formed on many other chondrules in this meteorite and both rims show irregular-shape surface morphology, suggesting that they were produced by brecciation in the same meteorite parent body. Texture, mineralogy, and chemical compositions of the multi-layered rim in the Y-75273 suggest that the outermost fine-grained rim was formed by parent-body process after inner coarse-grained rims were formed by multiple heating in the solar nebula.

Defocused electron beam analysis of fine-grained rims and matrix shows compositional variation: in a Si-Mg-Fe ternary diagram, the fine-grained-rims fall on the Fe-rich areas relative to solar, while matrix falls on the Si-rich areas relative to solar, suggesting that the fine-grained rims and matrix are different material. The constituent minerals of the fine-grained rims and matrix, such as olivine and pyroxene, differ in the chemical composition. Olivine composition of the fine-grained rim (Fa₇₇₋₈₀) differs from matrix (Fa₃₈₋₄₈), indicating that these olivines are not chemically equilibrated during thermal metamorphism. The mesostasis glass of the chondrules which is the most susceptible to alteration, is clear and seems not to have altered, suggesting that aqueous alteration did not cause the exchange of elements between the chondrules and the fine-grained rims and between the chondrules and the matrix. This suggests that the

difference in chemical composition between the fine-grained rim and the matrix was not established by secondary alteration, rather they are originally different material.

This compositional difference between matrix and fine-grained rims is observed in both Y-75273 and Y-74660. This suggests that the fine-grained materials in the LL chondrite formation region could have changed over time or location, because earlier-formed fine-grained rims differ from later-formed matrix material.

Keywords: Chondrule rim, LL chondrites, Fine-grained rim