Formation conditions of CAIs inferred from rare earth element abundance patterns of CAIs from Y-81020 chondrite.

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We analyzed rare earth element (REE) abundance patterns in 47 inclusions in Yamato 81020 (CO 3.0) meteorite using an ion microprobe, CAMECA ims-6f. They include various kinds of fine-grained inclusions, a few coarse-graind inclusions, and 17 amoeboid olivine aggregates (AOAs). The purpose of this study is to better understand the environments and formation processes of refractory inclusions based on their REE patterns. An important motivation of this study is to examine whether or not newly defined Modified Group I and Modified Group II patterns (Yamakawa, 2005) are also found in Yamato 81020 chondrite. These REE patterns were recently found in the Ningqiang (CV3) inclusions and named as new REE patterns: Modified Group II is a Group II-like (i.e., heavy-REE depleted) pattern with positive anomalies in Ce +Eu +Yb and Modified Group I is a nearly unfractionated pattern with positive anomalies in Ce +Eu +Yb.

The observed REE abundance patterns are grouped into the following four: (1) Flat with positive or negative anomalies in Eu and Yb (Group I, III and V), (2) Group II pattern, (3) Modified Group II pattern, and (4) Ce-depleted pattern. The fact that Modified Group II patterns were also found in four inclusions in Yamato 81020 suggests that Modified Group II pattern is not unique to the Ningqiang meteorite (CV3) but exist rather abundantly in refractory inclusions in various chondrite groups.

In order to understand formation conditions of these REE patterns, we performed simple condensation calculations of REEs. Modified Group II pattern was probably formed by condensation from a residual gas after removal of a dust (solid) component containing ultra-refractory heavy-REEs and some amount of light-REEs. Such dust-gas separation must occur at a temperature slightly lower than the case for the formation of Group II pattern. The observed Ce-depleted patterns may require evaporation of Ce under rather oxidizing conditions, where Ce became volatile compared with other REEs. The present results suggest considerable variations in the formation condition of refractory inclusions.