**RARE EARTH ELEMENT ABUNDANCES IN REFRACTORY INCLUSIONS FROM Y-81020 (CO3.0) CHONDRITE: EVIDENCE OF REE FRACTIONATION UNDER VARIABLE CONDITIONS.** H. Hiyagon[1] and M. Sasaki[1], [1]Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo (7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan. hiyagon@eps.s.u-tokyo.ac.jp)

**Introduction:** In the course of the systematic study on refractory inclusions in the Ningqiang meteorite [1], ion microprobe analyses of rare earth elements (REEs) have been performed and correlated positive anomalies in Ce (±Eu) +Yb have been found in some inclusions [2, 3]. Two different patterns are recognized: one is HREE-depleted patterns with positive anomalies in Ce ±Eu +Yb (named as modified Group II) and the other is almost flat (unfractionated) patterns with positive anomalies in Ce ±Eu +Yb (named as modified Group I). It was suggested that condensation from a fractionated gas, from which ultra-refractory HREE and some amount of LREE had been condensed and removed, would produce modified Group II patterns [4]. This REE fractionation condition is similar to that for the Group II pattern [5] but the temperature is slightly lower where LREE are also partly condensed. It was also suggested that incomplete separation of such dust from the gas would produce modified Group I patterns [4].

In order to see if such correlated positive anomalies in Ce ±Eu +Yb are common among refractory inclusions from different meteorite groups, we further conducted REE analyses on refractory inclusions from Yamato 81020 (CO3.0) chondrite, one of the most primitive CO chondrites.

**Samples and analytical conditions:** So far 10 inclusions have been analyzed for REE abundances: five AOAs or AOA-like inclusions (RI#5, RI#9, RI#25, RI#28 and RI#38), one melilite-rich (type A) inclusion (RI#8), one hibonite-melilite inclusion (RI#14), one melilite-spinel inclusion (RI#16), one melilite-perovskite inclusion (RI#17) and one pyroxene-spinel-plagioclase inclusion (RI#1). Most of them are small (typically ~100 μm in size) except for RI#8. RI#8 (~500 μm in diameter) consists mostly of gehlenitic melilite in the inner part surrounded by rim layers of spinel +perovskite +melilite +diopside. Its central part was possibly a cavity space now filled with fragments of this inclusion or matrix-like materials. REE analyses were preformed for the inner melilite and perovskite-rich part of the rim. RI#14 (~100 μm x ~60 μm in size) consists gehlenitic melilite, hibonite and some perovskite grains. The analyzed point contains hibonite with some melilite. RI#16 (~100 μm x ~60 μm in size) consists of gehlelitic melilite, spinel and small amount of perovskite and metallic Fe+Ni. The REE analysis was performed for melilite. RI#17 (totally ~100 μm in size) is composed of several 10-30 μm-sized grains, which consists mostly of melilite with some perovskite grains. The analyzed point contains melilite with some perovskite grains.

The analytical condition of REEs using an ion microprobe (CAMECA ims-6f) was essentially the same as described in [2, 3]. The $^{16}O^-$ primary beam was 20-30 μm in diameter and the intensity was ~1nA. The energy window was set to 30V and a 60V energy offset was applied to reduce the complex molecular ions. Major element peaks (e.g., $^{40}Ca^+$) and masses from 133 to 185 were analyzed and the signals were mathematically deconvolved into REEs (plus Ba and Hf) and REE-O signals, and converted to the concentrations of REEs, Ba and Hf using pre-determined production ratios of monoxide ions, REE-O$^+$/REE$^+$, and relative sensitivity factors of $(REE^+/Ca^+)_{\text{ion probe}}/(REE^+/Ca^+)_{\text{true}}$.

**Results and discussion:** All five AOAs and RI#1 (px-sp-pl inclusion) show flat (unfractionated) or nearly flat REE patterns with positive or negative Eu anomalies, though Eu abundance may be controlled by partitioning among different mineral phases (Fig.1). A melilite-rich inclusion, RI#8, esp., its perovskite-rich rim, shows some indication of HREE-depletion (Fig.2). RI#14 (hib-mel inclusion) and RI#17 (mel-pv inclusion) show HREE-depletion; RI#16 (sp-mel inclusion) also shows HREE-depletion or HREE-roll off. Depletion of HREE in these inclusions suggests condensation from the fractionated (HREE-depleted) gas (Group II). Among them, RI#17 also shows large excesses in Eu+Yb but without a Ce anomaly (Fig.3): the abundances of Eu (38xCI) and Yb (32xCI) are 5-6 times as high as LREE (~6xCI). Since the analyzed point contains perovskite grains, which usually have high abundances of REEs compared with melilite, the observed positive Eu anomaly may be real (i.e., not mineral-controlled) and may be representative of the bulk inclusion.

So far, REE patterns with correlated positive Ce±Eu+Yb anomalies are not found, different from the case for the Ningqiang meteoirte. This, however, may be due to limited number of analyses so far conducted (note that 5 out of 10 analyses were performed for AOAs in the present study), or possibly due to different frequency distributions of REE patterns among different meteorite types.

It is interesting to note that one inclusion (RI#17) shows HREE depletion with large positive anomalies in Eu+Yb but no anomaly in Ce (Fig.3), which is somewhat similar to the modified Group II pattern reported for the Ningqiang inclusions. There is a possibility that the REE pattern in RI#17 is produced through a process similar to that for the modified Group II pattern proposed by [4]. In the case of the solar oxygen fugacity, solid/gas separation at a temperature where condensation of ultra-refractory HREE and partial condensation of LREE occur would produce a positive Ce anomaly in the gas phase due to slightly volatile nature of Ce among LREE in such a condition [4]. In a more reducing condition, however, Ce becomes as refractory as other LREE and fractionation among LREE becomes smaller. This may be a possible condition for producing the REE pattern of RI#17. This suggests that REE fractionation (i.e., solid/gas separation) occurred under variable nebular conditions (different temperatures and oxygen fugacities). However, several problems remain. One problem is that Sm becomes relatively volatile among LREE at reducing conditions, so that increase in Sm abundance should be observed in the REE pattern, which, however, is not the case. More precise condensation calculations with variable conditions (P, T, dust-enrichment factor or oxygen fugacity, etc.) as well as more REE data on various types of inclusions are required to better understand the fractionation conditions of REEs in the early solar system.

**References:** [1] Lin Y. and Kimura M. (2003) *Geochim. Cosmochim. Acta, 67*, 2251-2267. [2] Hiyagon H. et al. (2004) *Meteoritics & Planet. Sci., 39*, A46. [3] Yamakawa A. et al. (2004) *Workshop on Chondrules & the Protoplanetary Disk (Abs)*, 225-226. [4] Hiyagon et al. (2005) *Meteoritics & Planet. Sci., 40*, A68. [5] Davis A. M. and Grossmam L. (1979) *Geochim. Cosmochim. Acta, 43*, 1611-1632.

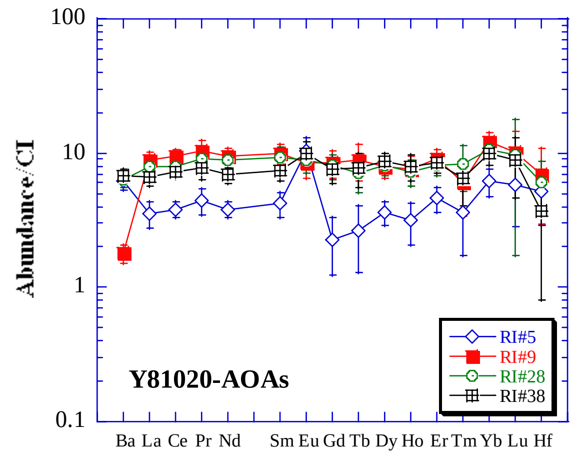


Fig.1 REE abundances of AOAs.

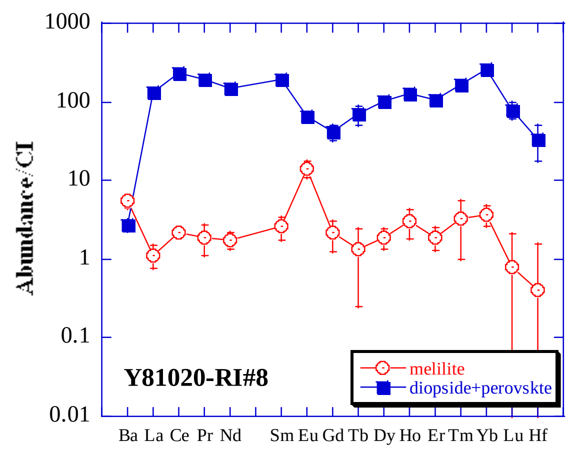


Fig.2 REE abundances in a melilite-rich inclusion RI#8.

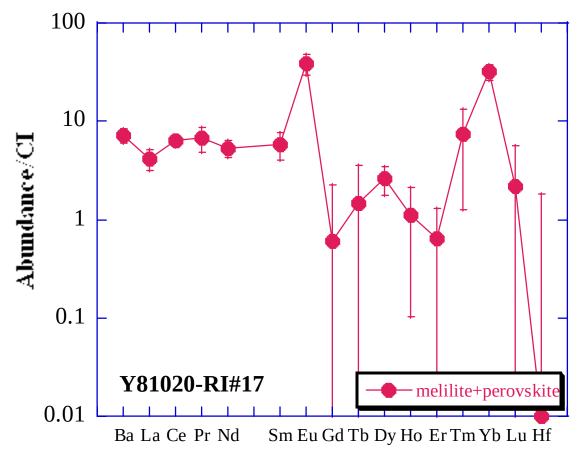


Fig.3 REE abundances in RI#17.