

REFRACTORY FORSTERITES FROM MURCHISON (CM2) AND YAMATO 81020 (CO3.0) CHONDRITES: CATHODOLUMINESCENCE, CHEMICAL COMPOSITIONS AND OXYGEN ISOTOPES. H. Hiyagon¹, N. Sugiura¹, M. Kimura² and A. Miyazaki¹, ¹Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, Tokyo 113-0033, Japan. (hiyagon@eps.s.u-tokyo.ac.jp), ²Faculty of Science, Ibaraki University, Mito 310-8512, Japan.

Introduction: Forsteritic olivine (FeO <1 wt%) with bright (blue) cathodoluminescence (CL) often occurs as isolated grains surrounded by matrix or as grains within chondrules. It is common in carbonaceous chondrites (CCs), but is also found in unequilibrated ordinary chondrites (UOCs) and even in R-chondrites. It has high concentrations of refractory lithophile elements (RLEs: Ca, Al, Ti, etc.) and is referred to as refractory forsterite (RF). The origin of RF is still controversial whether it formed through direct condensation from the solar nebula [e.g., 1-3] or formed from chondrule melts [e.g., 4-6]. Recently, Pack et al. [7] proposed a model, in which RF crystallized in a RLE-rich melt directly condensed from a solar nebula under a dust-enriched condition. In order to better understand the origin of RFs, we conducted chemical, CL, and O-isotopic studies on RFs from Murchison (CM2) and Yamato 81020 (CO3.0) chondrites. A preliminary study for Murchison RFs was reported in [8].

Samples : A 9.85 gram piece of the Murchison meteorite was freeze-thaw disaggregated and isolated olivine grains, both FeO-poor (RFs) and FeO-rich, as well as chondrules were handpicked, mounted on a slide glass (25mm in dia.) with epoxy together with San Carlos olivine and synthetic forsterite for O-isotope standards, and polished together. In the present study, 13 isolated RF grains were analyzed. Their shapes are euhedral, rounded or fragmental, and their size is ~200 to ~500 μ m in diameter. For comparison, some RFs, both as isolated grains and found within chondrules, on thin sections of Yamato 81020 (CO3.0) were also studied. Among them, Y81-Ch1, a porphyritic olivine-pyroxene chondrule of 150 μ m x 160 μ m in size, contains euhedral, apparently *in situ*-grown, RF grains (Fig.1).

Analytical conditions: The samples were first examined with a SEM (JEOL-5310) –EDS (Oxford Co.) for petrography and major element chemistry. Cathodo-luminescence images were taken with the MiniCL (Gatan Inc.) attached to the SEM using red/green/blue filters. Oxygen isotopes were analyzed with a CAMECA ims-6f ion microprobe using

analytical conditions similar to those described in [9]. The beam size was ~10 μ m in diameter. The samples were further analyzed with an EPMA for more precise determinations of minor element abundances in olivine (Ca, Al, Ti, Cr, Mn, V, etc.).

Results:

CL images: All the RFs show bright CL emission. Many of the isolated RF grains show zoning in CL images with darker CL regions in the margin. Some of them show irregular-shaped sharp boundaries between bright/dark CL regions [8]. Some of them contain spinel grains in the bright CL region [8]. Olivine phenocrysts in a chondrule Y81-Ch1, on the other hand, show brighter CL in the margin. The cause for this enhanced CL brightness is not certain at present, but may be due to slight enrichment of Mn and Cr in the margin.

Minor element chemistry: Bright CL regions of RFs from Murchison show high concentrations of CaO (up to 0.75 wt%), Al₂O₃ (up to 0.66 wt%), TiO₂ (up to 0.14 wt%) and V₂O₃ (up to 0.19 wt%), and low concentrations of FeO (0.0-0.3 wt%), Cr₂O₃ (0.01-0.2 wt%) and MnO (0.00-0.06 wt%). A CaO-FeO daigram is shown in Fig.2. One RF, MCFH-24, shows extremely low concentrations of FeO, Cr₂O₃, MnO and V₂O₃ (below detection limits of EPMA: <0.017, <0.006, <0.015 and <0.009 wt%, respectively), which are different from the trend of other RFs, and should be discussed separately. Darker CL regions tend to show lower Ca, Al, Ti, V and higher Fe, Cr, Mn concentrations. In some cases, however, no clear difference is observed in Fe and Cr concentrations between the bright/dark CL boundaries.

RFs in Y81020 show chemical compositions very similar to those of Murchison RFs, but tend to have higher concentrations of FeO (0.3-0.1.6 wt% for CaO >0.4 wt%) and Cr₂O₃ (0.06-0.36 wt% for CaO >0.4 wt%) (Fig.2). Euhedral olivine phenocrysts in Y81-Ch1 show the highest concentrations of CaO (up to 0.88 wt%) and V₂O₃ (up to 0.064 wt%) among all RFs, but their chemical composition as a whole is consistent with those for the other RFs.

Oxygen Isotopes of Murchison RFs: The obtained oxygen isotopic compositions for Murchison RFs are summarized in Fig.3. Both bright and dark CL regions and spinel grains enclosed in RFs were analyzed. Also shown for comparisons are terrestrial fractionation (TF) line and carbonaceous chondrite anhydrous minerals (CCAM) line. All the data fall in a surprisingly narrow region approximately on the CCAM line with $\delta^{17}\text{O}$ and $\delta^{18}\text{O} = -8 \pm 3$ and -5 ± 3 permil, respectively. No difference is observed in O isotopes among the bright CL regions, dark CL regions and even spinel grains. This suggests that all RFs in Murchison formed from a single O-isotopically homogeneous reservoir. Spinel is not relict but formed *in situ* with olivine.

Discussion: We have not yet reached a conclusion whether RFs formed through direct condensation from the nebula or they formed within a RLE-rich melt (18-20 wt% CaO) as proposed by Pack et al. [8]. Apparently many RFs seem to have experienced remelting (suggested by rounded-type RFs) or complex thermal histories (suggested by complex zoning in CL images). The problem for the latter model is lack of abundant melt phases around RFs. It seems also difficult to understand concentration profiles of CaO and other RLEs within RF grains: they are rather homogeneous for some RFs or they decrease toward the margin. The concentration profiles are inconsistent with those expected from a closed system crystallization model. An open system crystallization model [8] may be possible, but still has difficulties in explaining rather constant profiles for some RFs. The discovery of *in situ*-grown RFs in a chondrule Y81-Ch1 will cast new insights into the formation process of RFs. It contains a melt phase, which has long been missing. However, CaO content of the mesostasis is at most 15 wt%, which is not high enough for a melt phase in equilibrium with olivine with >0.8 wt% CaO. The bulk CaO content of this chondrule is even much lower. The formation process of Y81-Ch1 and its relation to other RFs has key importance to better understand the formation process of RFs.

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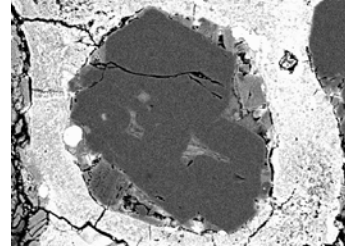


Fig.1 A backscattered electron image of a chondrule, Y81-Ch1, in Yamato 81020.

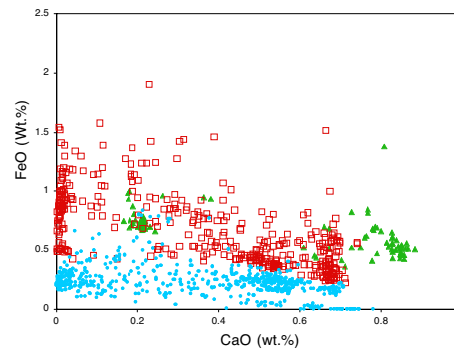


Fig.2 Correlation between FeO and CaO for isolated RF grains in Murchison (blue dots), in Y81020 (red squares), and RFs within chondrules in Y81020.

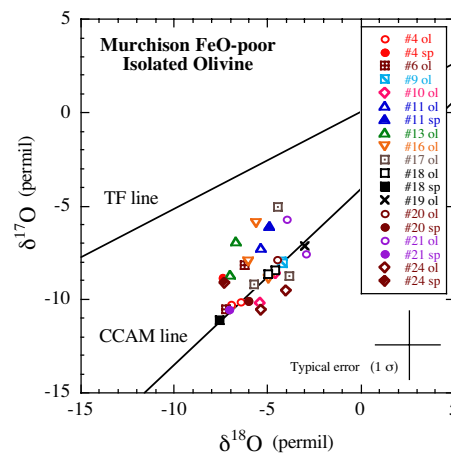


Fig.3 Oxygen isotopic compositions of isolated RF grains from Murchison.