

OXYGEN ISOTOPE SYSTEMATICS OF CHONDRULES FROM THE LEAST EQUILIBRATED H CHONDRITE. N. T. Kita¹, M. Kimura², T. Ushikubo¹, J. W. Valley¹ and L. E. Nyquist³, ¹University of Wisconsin-Madison, Madison WI 53706-1692, USA (noriko@geology.wisc.edu), ²Ibaraki University, Mito, Japan, ³NASA Johnson Space Center, Houston, TX 77058-3696, USA.

Introduction: Oxygen isotope compositions of bulk chondrules and their mineral separates in type 3 ordinary chondrites (UOC) show several ‰ variability in the oxygen three isotope diagram with slope of ~0.7 [1]. In contrast, ion microprobe analyses of olivine and pyroxene phenocrysts in ferromagnesian chondrules from LL 3.0-3.1 chondrites show mass dependent isotopic fractionation as large as 5‰ among type I (FeO-poor) chondrules, while type II (FeO-rich) chondrules show a narrow range ($\leq 1\%$) of compositions [2]. The $\Delta^{17}\text{O}$ ($=\delta^{17}\text{O}-0.52\times\delta^{18}\text{O}$) values of olivine and pyroxene in these chondrules show a peak at ~0.7‰ that are systematically lower than those of bulk chondrule analyses as well as the bulk LL chondrites [2]. Further analyses of glass in Semarkona chondrules show $\Delta^{17}\text{O}$ values as high as +5‰ with highly fractionated $\delta^{18}\text{O}$ (max +18‰), implying ^{16}O -poor glass in chondrules were altered as a result of hydration in the parent body at low temperature [3]. Thus, chondrules in LL3.0-3.1 chondrites do not provide any direct evidence of oxygen isotope exchange between solid precursor and ^{16}O -depleted gas during chondrule melting events.

To compare the difference and/or similarity between chondrules from LL and H chondrites, we initiated systematic investigations of oxygen isotopes in chondrules from Yamato 793408 (H3.2), one of the least equilibrated H chondrite [4]. In our preliminary study of 4 chondrules, we reported distinct oxygen isotope ratios from dusty olivine and refractory forsterite (RF) grains compared to their host chondrules and confirmed their relict origins [5].

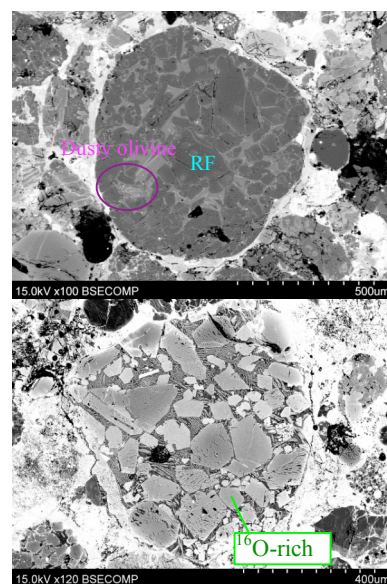
Samples and Methods: We prepared two thick-polished sections of Y-793408 (A1 and B1) and selected more than 50 chondrules to obtain their petrographic texture and mineral and bulk chemical compositions using electron microprobe. In section A1, we selected 21 chondrules, including 4 type IA, 6 type IAB, 4 type IB, 5 type IIA, 1 radial pyroxene (RP) and 1 cryptocrystalline (CC). Type IA chondrules were relatively smaller (100-300 μm) than other chondrules (mostly 300-500 μm). Oxygen isotope analyses of olivine and pyroxene in these 21 chondrules were performed with 10-15 μm spots using CAMECA IMS 1280 ion microprobe at the University of Wisconsin [6]. San Carlos olivine standard grains were mounted adjacent to the meteorite sample in epoxy. Chondrule analyses were bracketed by 8 sets of standard analyses

in order to correct instrumental bias on oxygen isotope analyses. External reproducibility of bracketing standards was typically better than 0.4‰ (2 SD) for $\delta^{18}\text{O}$, $\delta^{17}\text{O}$ and $\Delta^{17}\text{O}$ of 15 μm spot analyses and 0.7‰ for $\delta^{17}\text{O}$ and $\Delta^{17}\text{O}$ of 10 μm spot analyses. The analyses of chondrules in section B1 are in progress.

Results and Discussion: Since relict forsterite and dusty olivine grains were observed in chondrules in this meteorite [5], multiple analyses spots within a chondrule were selected from grains with ranges of compositions and textural contexts. As a result, internal heterogeneity in ^{16}O much beyond 1‰ level was found from two chondrules, implying that they contain ^{16}O -rich relict olivine grains (Fig. 1-2).

Chondrule A1-3 (type IAB) contains refractory forsterite ($\text{Fo}_{99.5}$), magnesian olivine of the host chondrule ($\text{Fo}_{95}-\text{Fo}_{98}$) and dusty olivine (~ Fo_{90}) in a single sample. As shown in Fig. 2, these three different olivine grains show distinct isotope ratios along Y&R line with $\delta^{18}\text{O}$ ~2‰, 4‰ and 5-6‰ for RF, dusty olivine and host olivine, respectively. The result indicates the chondrule A1-3 only partially melted during chondrule formation and preserved precursor olivine grains with different isotope ratios. The rim of RF and low Ca pyroxene that might be overgrown or crystallized from the melt show isotope ratios between RF and host olivine, indicating oxygen isotope mixing occurred during chondrule melting.

Fig. 1. (upper) type IAB chondrule A1-3, containing RF at the center and small grain of dusty olivine. (lower) type IIA chondrule A1-10 with a wide range of olivine compositions.



Chondrule A1-10 (type IIA) contains olivine phenocrysts with a wide range of compositions ($F_{O_{75}}-F_{O_{87}}$). Some of them show a texture of resorption. One olivine grain with $F_{O_{82}}$ shows oxygen isotope ratios of $\delta^{18}O=1\%$ and $\delta^{17}O=-1\%$, which is significantly ^{16}O -rich compared to other grains (Fig. 2). Other data with more normal isotope ratios also plot along the Y&R line, indicating that the ^{16}O -rich precursor was incompletely mixed throughout the chondrule. It is noted that ^{16}O -rich olivine grain is not the most magnesian olivine in this chondrule, but showing a slight enhancement in Al_2O_3 and Cr_2O_3 compared to other olivine grains. For this reason, the precursor of this chondrule might contain RF similar to that in A1-3.

Three more type IIA chondrules also give a hint of internal heterogeneity at the 0.5-1.5‰ level. In these chondrules, ^{16}O -rich olivine grains are also recognized as the most magnesian olivine with slightly increased Al_2O_3 and Cr_2O_3 contents. Therefore, it is likely to consider RF to be common precursor component in ordinary chondrite chondrules. In other chondrules, we observed slight increase of $\Delta^{17}O$ among olivine with higher Fa contents and Ca rich pyroxene rim, which crystallized at the latest stage of chondrule melting. More detailed comparison between oxygen isotope and petrography for individual chondrules are required to decode the mechanism of mixing of distinct oxygen isotope reservoirs during their formation.

Oxygen Isotope among Chondrule Groups: The averages of multiple spot analyses for individual chondrules are shown in Fig. 3. In chondrules with ^{16}O -rich grains, the average values were calculated using host normal olivine and pyroxene data. Oxygen isotope ratios in type I chondrules widely spread both along TF and Y&R lines. Olivine-rich type IA chondrules are lower in $\delta^{18}O$ and plot left of Y&R line, while types IAB and IB are higher in $\delta^{18}O$. The chondrule A1-N12 is glass-rich type IB and shows the most ^{16}O -rich composition. In contrast, oxygen isotope ratios in type II chondrules are confined to a narrower range slightly above the bulk meteorite ratios. These systematic oxygen isotope variations with chondrule types are identical to those reported for LL3.0-3.1 chondrites. Furthermore, the average of $\Delta^{17}O$ of 21 chondrules in Y-793408 is $\sim 0.7\%$, which is very similar to that of LL3.0-3.1 chondrites [2]. Therefore, chondrules in both types of chondrites are very similar in oxygen isotopes even though the bulk oxygen isotope ratios of host meteorites are significantly different. Slightly elevated $\Delta^{17}O$ in bulk L and LL ordinary chondrites compared to H chondrites may be caused by an aqueous component with higher $\Delta^{17}O$ accreted to their parent bodies [3, 8].

References: [1] Clayton R. N. et al. (1991) *GCA*, 55, 2317-2337. [2] Kita N. T. et al. (2006) *LPS XXXVII*, Abstract #1496. [3] Kita N. T. et al. (2007) *LPS XXXVIII*, Abstract #1791. [4] Kimura M. et al. (2002) *Meteoritics & Planet. Sci.*, 37, 1417-1434. [5] Kita N. T. et al. (2007) *Meteoritics & Planet. Sci.*, 42, A84. [6] Kita N. T. et al. (2007) *LPS XXXVIII*, Abstract #1981. [7] Young E. D. and Russell S. S. (1998) *Science* 282, 452-455. [8] Choi B-G. et al. (1998) *Nature* 392, 577-579.

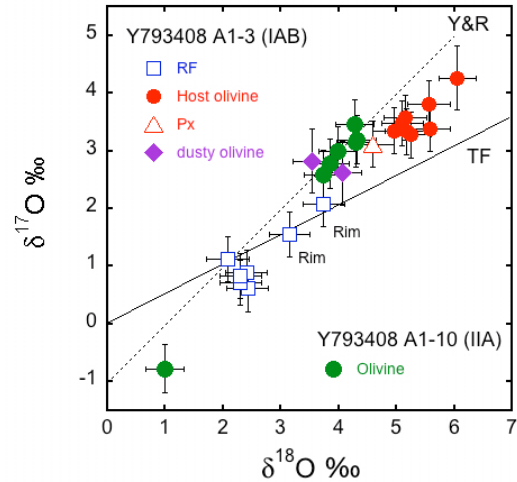


Fig. 2. Oxygen isotope ratios of individual spots in chondrule A1-3 and A1-10. Solid line is terrestrial mass fractionation line (TF) and dashed line is Young and Russell (Y&R) line, which passes bulk equilibrated ordinary chondrites values with slope of 1 [7]. Error bars are 2 SE.

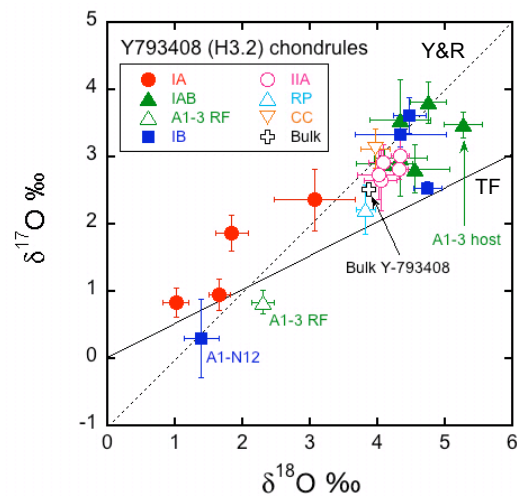


Fig. 3. Oxygen isotope ratios of individual chondrules in Y-793408 section A1. The averages of multiple spot analyses are shown except for A1-3 showing both ^{16}O -rich refractory forsterite and ^{16}O -poor host olivine. Bulk meteorite data are from [4]. Error bars are 2 SE of the mean.