

OXYGEN ISOTOPIC COMPOSITIONS OF CHONDRULE GLASSES IN SEMARKONA (LL3.0): SEARCH FOR ^{16}O -DEPLETED COMPONENTS IN CHONDRULES. N. T. Kita¹, H. Nagahara², S. Tachibana², J. H. Founelle¹, and J. W. Valley¹, ¹Department of Geology and Geophysics, University of Wisconsin-Madison, 1215 W. Dayton St., Madison WI 53706-1692 (noriko@geology.wisc.edu), ²Department of Earth and Planetary Science, University of Tokyo, 7-3-1 Hongo, Tokyo 113-0033, Japan.

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 [1-2]. In contrast, ion microprobe analyses of olivine and pyroxene phenocrysts in ferromagnesian chondrules from Semarkona (LL3.0), Bishunpur and Krymka (LL3.1) 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 near the average of type I chondrule trend [3]. The $\Delta^{17}\text{O}$ ($=\delta^{17}\text{O}-0.525\times\delta^{18}\text{O}$) values of olivine and pyroxene in these chondrules show a peak at $\sim 0.7\%$, and are systematically lower than those of bulk chondrule analyses as well as the bulk LL chondrites, indicating the chondrule glass is most likely the host for high $\Delta^{17}\text{O}$ values [2]. High $\Delta^{17}\text{O}$ in chondrule glass could be acquired either during chondrule forming melting by oxygen isotope exchange with ^{16}O -depleted nebula gas or in the meteorite parent body by the interaction with aqueous fluid elevated in $\Delta^{17}\text{O}$.

Some chondrules contain clinopyroxene (cpx) as microcrystallites in glass or at the rim of the phenocrysts adjacent to glass. Comparison between oxygen isotopes in cpx and glass may be useful to resolve the origin of the high $\Delta^{17}\text{O}$ in chondrules, because glass would be more susceptible to any secondary alteration process than clinopyroxene. In this study, we analyzed glass and clinopyroxene in chondrules from Semarkona in order to evaluate the distribution of high $\Delta^{17}\text{O}$ in chondrule mesostasis.

Samples: We studied six chondrules from Semarkona (LL3.0) that were studied previously for high precision oxygen isotope analyses of mafic minerals [3]. They include type IA, IB, IIA and IIAB (Fig.1). A type IA chondrule CH44 is a rare ^{16}O -rich chondrule having olivine with heterogeneous $\Delta^{17}\text{O}$ distributions from -4 to -0.5% . Other chondrules did not show significant internal heterogeneity among phenocrysts [3]. The Al-Mg system of two IIAB chondrules, CH4 and CH36, were obtained previously by [4].

Ion Microprobe Analyses: We used a CAMECA IMS 1280 ion microprobe at the University of Wisconsin-Madison for oxygen isotope analyses using multi-collection mode. The primary Cs^+ ions were focused to

$\sim 5\mu\text{m}$ spot with intensity of 0.5nA and the secondary ^{16}O intensity was $\sim 4\times 10^8$ cps. In this condition, ^{16}O and ^{18}O were collected using multicollector Faraday Cups, while ^{17}O was collected using an Electron Multiplier. Other conditions were similar to those in [3]. The reproducibility of repeated analyses of San Carlos olivine standard was $0.5-1\%$ in 2σ on both $\delta^{17}\text{O}$ and $\delta^{18}\text{O}$. For olivine and pyroxene, we used Fo89, En97, and diopside standards to correct instrumental mass fractionation. The empirical instrumental mass fractionation correction factor for glass was estimated using multiple silicate glass standards (including plagioclase, dacite, andesite and rhyolite glass) as a linear function of their oxide contents [5]. Such correction may not cause systematic error more than 1% and does not affect $\Delta^{17}\text{O}$ values. After the ion microprobe analyses, individual spot positions and major element compositions of glass at each location were analyzed using an electron probe micro-analyzer (EPMA).

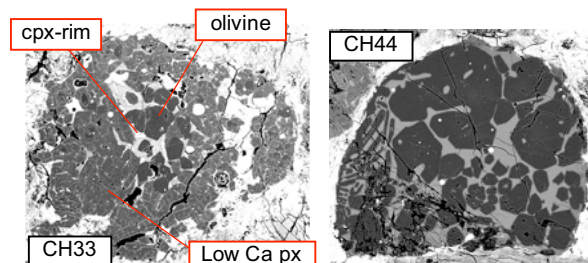


Fig. 1. (left) CH33 type IB chondrule contains larger olivine phenocryst at the center. Al-rich cpx appears at the rim of olivine and low Ca-pyroxene. (right) CH44 type IA chondrule consists of forsterite and Ca, Al-rich glass. Forsterite grains are heterogeneous in ^{16}O .

Results: The results of oxygen isotope analyses from CH33, CH11 (IB), CH52 (IIA), CH4 and CH36 (IIAB) are shown in Fig. 2. All the glass data show heavier oxygen isotope compositions compared to co-existing olivine/pyroxene phenocrysts. The differences in $\delta^{18}\text{O}$ between glass and phenocrysts were variable from 2% in CH33 to $\sim 14\%$ in CH36. The highest $\delta^{18}\text{O}$ and $\delta^{17}\text{O}$ in glass was $\sim 18\%$ and 14% in CH36 with highly elevated $\Delta^{17}\text{O}=5\%$. This is by far the heaviest oxygen observed from chondrules in UOCs and the $\Delta^{17}\text{O}$ value of 5% is very similar to that of magnetite in Semarkona [6]. Analyses of clean cpx in CH33,

CH11 (rim) and CH4 (small crystal in glass) are consistent with those of phenocryst olivine and low Ca-pyroxene. Analyses of cpx in CH52 and CH36 were all mixed with glass because of small grain sizes, and the $\delta^{18}\text{O}$ and $\delta^{17}\text{O}$ values were significantly lower than those in glass. These results indicate that cpx did not acquire the high $\Delta^{17}\text{O}$ values observed in glass, even though they should have crystallized from the melt at the same time. In addition, olivine and pyroxene phenocrysts in most chondrules from LL3.0-3.1 did not show internal heterogeneity of oxygen isotope compositions [3]. Therefore, oxygen isotope exchange with ^{16}O -depleted nebula gas during the chondrule-forming melting event could have been very limited and may not have played a major role in producing variations along the Y&R line among bulk UOC chondrules.

The result of oxygen isotope analyses in CH44 is shown in Fig. 3. The analyses of glass show ^{16}O -rich compositions very close to ^{16}O -rich forsterite. Small euhedral forsterite and lath shaped forsterite at the periphery of the chondrule were found to be most ^{16}O -rich ($\Delta^{17}\text{O} = -4.4\text{‰}$), while the interior of larger forsterite grains were ^{16}O -poor ($\Delta^{17}\text{O} = -1\text{‰}$). These observations indicate ^{16}O -poor olivine to be relict grains, rather than ^{16}O -rich ones.

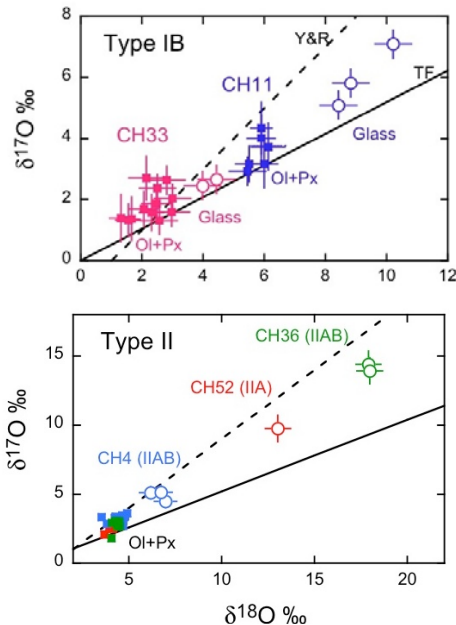


Fig. 2. Oxygen isotopic compositions of phenocrysts (solid symbols) and glass (open symbols) in ferromagnesian chondrules in Semarkona. Phenocryst data include those in [3]. “Y&R” is anhydrous CAI mixing line [7] and “TF” is terrestrial mass fractionation line.

Discussion: The experimental study of oxygen isotopic exchange between chondrule analogous melts and water vapor indicate multiple melting events are

needed if a large degree of oxygen isotopic exchange occurred between ^{16}O -rich chondrule precursor and ^{16}O -poor nebula gas [8]. Our ion microprobe data do not indicate extensive oxygen isotopic exchange with ^{16}O -poor nebula gas during chondrule melting, either because the cooling rate was too fast to allow isotopic exchange processes or oxygen isotope composition of nebula gas in the UOC chondrule forming region was similar to that of solid precursors.

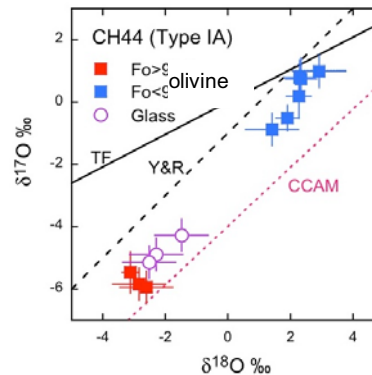


Fig. 3. Oxygen isotope compositions of olivine (solid square) and glass (open circle) in CH44. ^{16}O -rich and poor olivines are shown as red and blue, respectively.

In the case of CH44, chondrule precursors similar to those in carbonaceous chondrites might be mixed with forsterite fragments from a normal UOC chondrule. The oxygen isotope compositions in the melt might become less ^{16}O -rich compared to the initial conditions by the mixing with ^{16}O -poor relict forsterite. If CH44 formed in the UOC chondrule forming region, the ^{16}O -rich glass compositions in the chondrule also argue against the effective isotopic exchange with ^{16}O -poor nebula gases.

The presence of localized high $\Delta^{17}\text{O}$ components in FeO-rich chondrule glass is most likely the result of alteration of glass by fluid in the parent body [9-10]. However, chondrule glass studied here does not show obvious textural and chemical evidence of alteration and some glass analyses were made in the interior of chondrules. More detailed analyses may be needed to clarify if the high $\Delta^{17}\text{O}$ in glass is primary signature of UOC chondrules.

References: [1] Clayton R. N. et al. (1991) *GCA*, 55, 2317-2337. [2] Bridges J. C. et al. (1999) *GCA*, 63, 945-951. [3] Kita N.T. et al. *LPS XXXVII* Abstract# 1496. [4] Kita et al. (2000) *GCA*, 64, 3913-3922. [5] Kita et al. (2007), this volume. [6] Choi B-G. et al. (1998) *Nature* 392, 577-579. [7] Young E. D. and Russell S. S. (1998) *Science* 282, 452-455. [8] Yu Y. et al. (1995) *GCA* 59, 2095-2104. [9] Alexander C. M. O'D. et al. (1989) *GCA* 53, 3045-3057. [10] Grossman J. N. et al. (2000) *Meteoritics & Planet. Sci.*, 35, 467-486.