OXYGEN ISOTOPIC COMPOSITIONS OF PHENOCRYSTS IN CHONDRULES FROM THE PRIMITIVE CARBONACEOUS CHONDRITE ACFER 094. T. Ushikubo[1], M. Kimura[2], N. T. Kita[1], and J. W. Valley[1], [1]Department of Geology and Geophysics, University of Wisconsin-Madison, Madison, WI 53706-1692, USA (ushi@geology.wisc.edu), [2]Faculty of Science, Ibaraki University, Mito, 310-8512, Japan.

Introduction: Chondrules are small igneous silicate spherules and are abundant in primitive meteorites, implying that the melting of silicate particles was a common phenomenon in the solar nebula. However, their formation process and their precursor are still in controversy [1]. Oxygen isotopic composition of chondrules could be the useful information to understand the origin of chondrules because it is expected that the observed the variation in O isotopic composition of chondrules would relate to precursor of chondrules and/or environment of the chondrule formation [2].

Previously, we developed *in-situ*, high precision O isotope analysis with an ion microprobe and measured O isotopic compositions of chondrules from Semarkona (LL3.0) and Y-793408 (H3.2). We identified that some chondrules have O isotopic heterogeneity resulting from an incomplete isotopic exchange during chondrule formation and a later parent body alteration of glass even in the least equilibrated chondrites [3,4]. In this study, we will report O isotopic compositions of phenocrysts from chondrules in the primitive carbonaceous chondrite Acfer 094, which is one of the least equilibrated carbonaceous chondrites [5] and is appropriate to compare the characteristics of chondrules between carbonaceous chondrites and ordinary chondrites.

Samples and Methods: We studied 20 type I (FeO-poor) chondrules, 8 type II (FeO-rich) chondrules, 1 Al-rich chondrule, and 3 isolated olivines (100 to 600 μm in size) of the Acfer 094 polished thin section (USNM 7233-8). Among them, 6 type I chondrules and 1 isolated olivine contain refractory forsterite (RF) which shows bright blue cathodoluminescence (CL) [e.g. 6]. Because of the limitation of the spot size of high precision O three isotope analysis (10 to 15 μm in diameter), we mainly focused on olivine and low Ca pyoxene phenocrysts in porphyritic chondrules and isolated olivines.

Petrographic and CL observations were performed by Hitachi S-3400N SEM at UW-Madison. Chemical composition of samples was measured by JEOL 733 EPMA at Ibaraki University. Oxygen isotopes were analyzed by the Wisc-SIMS Cameca IMS-1280 ion microprobe at UW-Madison. A primary Cs^+ beam was set to a size of 10×15 μm in diameter with a current of ~2.5 nA. Secondary O^- ions were detected with three Faraday cups simultaneously. Typical count rates of $^{16}O^-$, $^{17}O^-$, and $^{18}O^-$ were 2×10^9, 8×10^5, and 4×10^6 cps, respectively. Other analytical conditions and measurement procedures were similar to those in [7]. External reproducibility of O isotope analysis of the standard San Carlos olivine was typically 0.3 ‰ for $\delta^{18}O$ and 0.7 ‰ for $\delta^{17}O$ and $\Delta^{17}O$ (=$\delta^{17}O$-0.52× $\delta^{18}O$), respectively (2SD).

Results and Discussion: We obtained 191 O isotope data of olivine, low-Ca pyroxene, and high-Ca pyroxene from chondrules and isolated olivines (2 to 11 spots each). The data are mostly distributed between the CCAM line [8] and the Y&R line [9] (Fig. 1). The most anomalous O isotopic composition observed in this study is $\delta^{18}O$=-43.4±0.3 and $\delta^{17}O$=-45.6±0.5 (2SD), which is close to those observed in chondrules from CV, CO chondrites [10,11] and the comet Wild 2 [12]. 10 out of 14 type I (no-RF) chondrules, 2 out of 6 RF-bearing type I chondrule, and 5

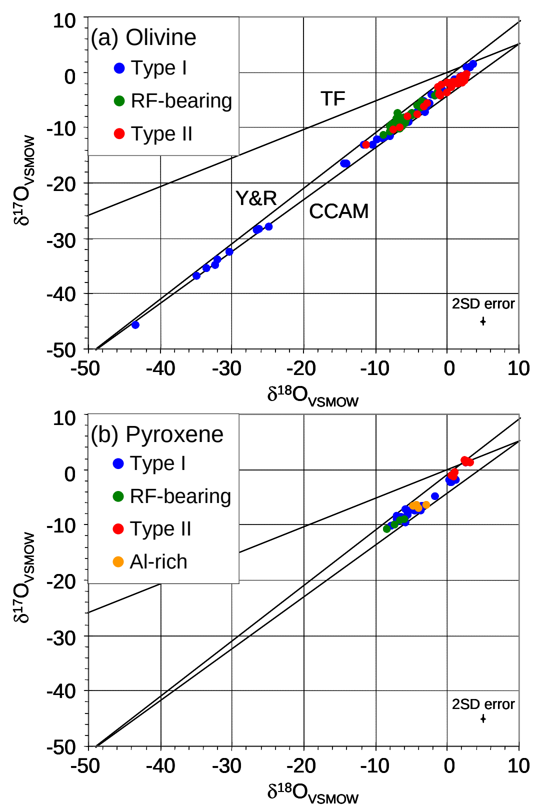

Fig.1 Oxygen isotopic compositions of (a) olivine and (b) pyroxene of chondrules from Acfer 094. TF, Y&R, and CCAM represent the terrestrial fractionation line, the Young & Russel line, and the carbonaceous chondrite anhydrous mineral line, respectively. Typical errors (2SD) are shown at a lower-right in each panel.

out of 8 type II chondrules show a variation in $\Delta^{17}O$ larger than the analytical reproducibility (2SD). Oxygen isotopic compositions of olivine (Fig. 1a) show wider variation than those of pyroxene (Fig. 1b). In addition, $\Delta^{17}O$ of pyroxene grains within each chondrule is homogeneous (within ±0.7 ‰) with the exception of a type I chondrule G68 (Fig. 2a). These imply that some olivine grains are relict grains and that their O isotopic compositions were not equilibrated with that of a silicate melt during the final chondrule melting process. It is worth mentioning that O isotopic compositions of pyroxene in RF-bearing type I tend to range at the ^{16}O-rich end of whole pyroxene data and those in type II chondrules tend to range at the ^{16}O-poor end (Fig. 1b) although the number of data is limited.

It has been shown that some olivine grains have O isotopic compositions that are distinct from those of other phases in the same chondrule, implying such olivine grains remained unmelted during a chondrule formation and could preserve O isotopic composition of precursors [e.g. 10-15]. In most cases, the O isotopic anomaly observed in olivine grains is ^{16}O-rich relative to other grains in the same chondrule (e.g. Fig. 2a). However, we found 3 type I chondrules that have olivine grains whose O isotopic compositions are ^{16}O-poor by +1 to +3 ‰ in $\Delta^{17}O$ relative to those of other olivine and pyroxene grains in the same chondrule (e.g. a type I chondrule G46; Fig. 2b). Similar olivine grains has been observed in an ordinary chondrite and carbonaceous chondrites [13-15]. Assuming an open system for chondrule formation and crystallization of pyroxene from a silicate melt, it is expected that O isotopic composition of pyroxene is strongly affected by interaction with the surrounding nebular gas [16,17]. If this is the case, the existence of ^{16}O-poor olivine in chondrules is not consistent with a simple mixing between ^{16}O-rich precursor and ^{16}O-poor nebular gas ($\Delta^{17}O \geq 0$ ‰) during a chondrule formation as suggested in [18]. The recognition that some chondrules have ^{16}O-poor olivines indicates that their precursors formed in a ^{16}O-poor environment and were processed after they moved to a relatively ^{16}O-rich environment, suggesting the existence of relatively ^{16}O-rich nebular gas ($\Delta^{17}O \leq -5$ ‰) when chondrule formed.

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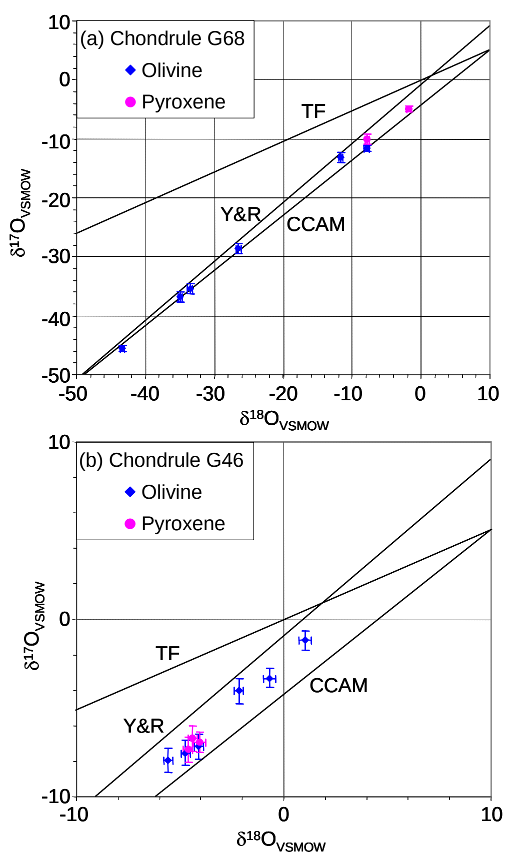

Fig.2 Examples of O isotopic compositions of relict olivine in (a) the chondrule G68 and (b) the chondrule G46. TF, Y&R, and CCAM are the same as Fig.1. Errors are 2SD.