SIMS measurements on oxygen-isotopic compositions of chondrules and matrix in the Yamato 691 EH3 chondrite.

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Introduction: Whole rocks, chondrules and matrix from the same chondrite group typically have the same or very similar oxygen-isotopic compositions [e.g., 1]. Among the three major clans of chondrites, enstatite chondrites (ECs) have the most uniform oxygen isotopic compositions (Fig. 1).

In order to study oxygen-isotopic heterogeneity of ECs in microscale, we carried out SIMS measurements on chondrules and matrix of the EH3 chondrite,Yamato 691 (hereafter Y691). We chose Y691 because it is the one of the most primitive ECs [2] and contains fine-grained matrix material [3, 4]. Bulk oxygen-isotopic compositions of Y691 were reported in [5]. SIMS measurements on pyroxenes and olivine in EH3 Sahara 97159 EH3 chondrite have also been reported [6].

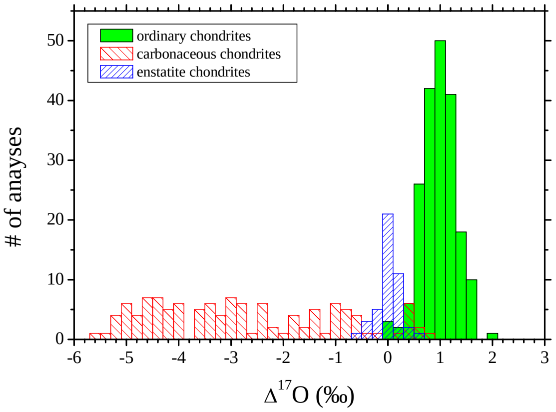

Fig. 1. Histogram showing ranges of $\Delta^{17}O$ values of whole rocks and chondrules of ordinary, carbonaceous and enstatite chondrite falls measured by Clayton and coworkers [5, 7-10]. The range of enstatite chondrites is significantly narrower than those of carbonaceous and ordinary chondrites. Whole-rock data for enstatite chondrites using CO_2 laser techniques show a similar range [11]

Analytical methods: Oxygen-isotopic compositions of mineral phases in 35 chondrules and 5 patches of matrix in Y691 were measured with the Cameca 7f GEO at California Institute of Technology. Some analyses of matrix and adjacent chondrules were reported in [4]. A defocused Cs^+ beam of ~ 2nA in intensity and ~ 30 μm in diameter was used to sputter the carbon-coated sample surface and to produce secondary ions. Two different analytical procedures were applied. First, we used a low mass resolution of ~1500 to measure only ^{18}O and ^{16}O ions using Faraday cups. A total of 70 spot analyses on olivine and pyroxene in chondrules were made with this mode; typical errors in individual measurements were 0.3-0.5 ‰ (1σ). Three-isotope measurements were then carried out with a mass resolution of ~ 6,000 in order to separate the $^{16}OH^-$ peak from the $^{17}O^-$ peak. Only $^{16}O^-$ ions were measured with the Faraday cup, while $^{17}O^-$ and $^{18}O^-$ were measured with an electron multiplier. A total of 21 spots on chondrules and 9 spots on matrix were made; typical errors in individual measurements were 0.5-1 ‰ (1σ). San Carlos olivine was used as a standard. Because matrix effects were neither monitored nor corrected, errors along fractionation lines could be somewhat larger than quoted.

Oxygen-isotopic compositions: The range of $\delta^{18}O$ values of olivine and pyroxenes in chondrules measured with low mass resolution (high transmission) is shown in Fig. 2. The average $\delta^{18}O$ value of 70 measurements is 4.2‰, which is similar to bulk Y691 ($\delta^{18}O$ = 4.83, $\delta^{17}O$ = 2.46, $\Delta^{17}O$ = -0.05 [5]). Since we only used San Carlos olivine as a standard (i.e., instrumental fractionation for pyroxene was not properly corrected), our data do not allow us to assess the difference between averages of olivine and pyroxene.

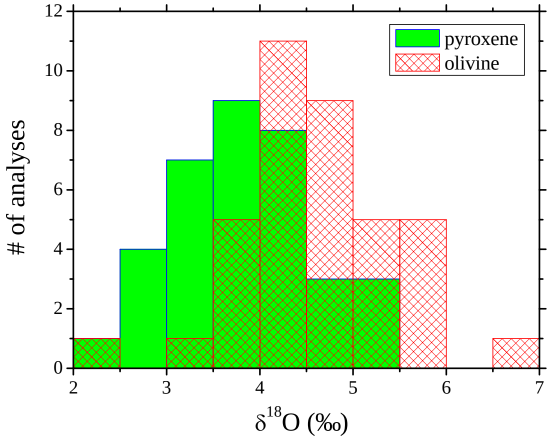

Fig. 2. Histogram showing ranges of $\delta^{18}O$ values of olivine and pyroxene in chondrules of Y691.

Oxygen-isotopic compositions of 9 spots on matrix and 21 spots on chondrules with high mass resolution are summarized in Fig. 3. The range of $\delta^{18}O$ values of matrix is larger than that of chondrules possibly due to larger counting errors and instrumental mass fractionations. Considering these artifical effects and our analytical uncertainties, we refer no significant difference between the oxygen-isotopic compositions of chondrules and matrix.

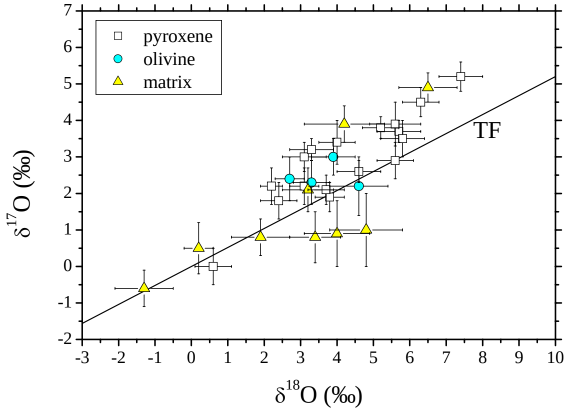

Fig. 3. Oxygen-isotopic compositions of olivine and pyroxene in chondrules and matrix of EH3 Y691.

Discussion and conclusions: Our data confirm previous studies showing oxygen-isotopic homogeneity in ECs relative to the other chondrites even in microscale. These results show that chondrules and matrix in ECs have very similar oxygen-isotopic compositions.

Oxygen-isotopic compositions of chondritic material can be either homogenized or rendered more variable by nebular and parent-body processes. Because Y691 is one of the most primitive ECs [2, 4], one can rule out the possibility that oxygen-isotopic homogeneity was achieved by parent-body processes. Therefore, EC chondrules must either have formed from precursor materials that had uniform oxygen-isotopic compositions or they experienced near-complete isotopic mixing during chondrule formation.

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