OXYGEN ISOTOPIC COMPOSITION OF REFRACTORY FORSTERITE IN R-CHONDRITE DAR AL GANI 013, UNEQUILIBRATED ORDINARY, AND CARBONACEOUS CHONDRITES. A. Pack[1], H. Yurimoto[2] and H. Palme[1], [1]Institut für Mineralogie und Geochemie, Zülpicher Straße 49b, D-50674 Köln (Germany), e-mail: pack@min.uni-koeln.de, [2]Department of Earth and Planetary Sciences, Tokyo Institute of Technology, Meguro, Tokyo 152-8551 (Japan)

Introduction: Refractory forsterite (RF) is characterized by high contents of refractory lithophile elements (RLEs) including Ca, Al, Ti, Sc, V, REE and by low contents of FeO (0.2 to~1 wt.%) [1–5 and references therein]. RF is found in chondrules and matrices of carbonaceous chondrites and unequilibrated ordinary chondrites. Additionally, RF also occurs in chondrites of the highly oxidized R-group [6,7]. RF in carbonaceous and ordinary chondrites is typically enriched in ^{16}O relative to the composition of the host meteorite and meteorite chondrules [8–10].

Here, we present the results of *in-situ* oxygen isotope measurements of RF in R-chondrite *Dar al Gani 013* (R3–5), three ordinary chondrites (*Dar al Gani 369* L(H)3, *Dar al Gani 378* H(L)3, *Chainpur* LL3.4), and carbonaceous chondrites (*Renazzo*, C2R; *Murchison*, C2M; Allende, C3V) by secondary ion mass spectrometry.

Analytical procedure: A Jeol 8900RL microprobe was used for chemical analyses and for BSE- and CL-imaging. Oxygen isotope measurements were performed using the TiTech Cameca ims-1270 ion probe. The mass-filtered 20 keV primary Cs^+-ion beam (~3 pA) was adjusted to obtain a secondary ion beam intensity of ~$4\cdot10^5$ cts/s (^{16}O). Secondary ions were measured on masses ^{16}O tail, ^{16}O, ^{17}O, ^{16}OH, and ^{18}O at a mass resolution of ~6000. The 1σ-precision of a single analysis is ±1.5‰ for $\delta^{18}O$ and ±2.5‰ for $\delta^{17}O$ (for details see Yurimoto et al., 1998). The accurracy including instrumental mass fractionation is better than ±5‰. Calibration was performed on a San Carlos olivine and a Russian spinel.

Results: *Dar al Gani 013 (R3-6).* Two isolated RF grains (RF08 and RF10, CaO 0.6-0.7 wt.%) from an unequilibrated lithology of DaG 013 exhibit a considerable enrichment in ^{16}O with $\delta^{17}O = -12$‰ and $\delta^{18}O = -13$‰ and $\Delta^{17}O \approx -5$‰ (bulk of R-chondrites: $\Delta^{17}O \approx +3$‰ [6]). Fayalitic rims of RF08 and RF10 are less enriched in ^{16}O ($\delta^{17}O = \delta^{18}O \approx -1$‰, $\Delta^{17}O \approx -1$‰) and reflect exchange with an ^{16}O depleted reservoir, however, without attaining equilibrium with the matrix. A single matrix fayalite was measured in DaG 013 showing a strong depletion in ^{16}O with $\delta^{17}O = +9$‰ and $\delta^{18}O = +3$‰ ($\Delta^{17}O = +8$‰).

Dar al Gani 369 (L(H)3). Chondrule RF02 is a porphyric type-IA chondrule with vitreous mesostasis. A single large olivine grain has a refractory CL-emitting core with a melt inclusion. The refractory forsterite has, with some variability, an oxygen isotope composition of $\delta^{17}O = \delta^{18}O \approx -1$‰. The melt inclusion has a composition of $\delta^{17}O = \delta^{18}O = +2$‰. The surrounding vitreous mesostasis is considerably depleted in ^{16}O having a composition of $\delta^{17}O = +14$‰ and $\delta^{18}O = +8$‰ ($\Delta^{17}O = +10$‰). Fayalite-rich olivine in the same chondrule has a composition indistinguishable from the forsterite and the melt inclusion of $\delta^{17}O = \delta^{18}O = 0$‰.

A single RF in chondrule RF05 and an isolated RF (i-01) were isotopically characterized. Both are not enriched in ^{16}O ($\delta^{17}O \approx +4$‰ and $\delta^{18}O \approx +6$‰, $\Delta^{17}O \approx +1$‰).

Dar al Gani 378 (H(L)3). RF from three chondrules (RF03–05) have very different O-isotopic composition. RF03 is a small Type-IA chondrule with refractory cores in the fayalitic olivines ($\delta^{17}O = +5$‰, $\delta^{18}O = +6$‰, 0.36 wt.% CaO). RF04 is a small barred olivine chondrule with refractory cores (olivines ($\delta^{17}O = +5$‰, $\delta^{18}O = +6$‰, 0.36 wt.% CaO). RF05 is also a Type-IA chondrule with a small RF core ($\delta^{17}O = -6$‰, $\delta^{18}O = -4$‰, $\Delta^{17}O \approx -5$‰).

Chainpur (LL3.4). Chondrule ChaXc1 is a macroporphyric chondrule consisting of a single, euhedral refractory forsterite (0.6…0.7 wt.% CaO, 1.1 mol% *fa*) grain (~300 µm across) embedded in a fine grained devitrified mesostasis. The forsterite hosts spinel (8.9 mol% *herc*) and a meltinclusion. Small, FeO-rich olivines occur in the mesostasis.

The forsterite was measured to have an oxygen isotope composition of $\delta^{17}O = -9$‰ and $\delta^{18}O = +11$‰ ($\Delta^{17}O = -3$‰). Spinel in the large forsterite is slightly more enriched in ^{16}O ($\delta^{17}O = -15$‰ and $\delta^{18}O = +16$‰, $\Delta^{17}O = -7$‰) compared to the olivine host. The melt inclusion within the forsterite has $\delta^{17}O = +1$‰ and $\delta^{18}O = +1$‰ ($\Delta^{17}O = 0$‰). The surrounding devitrified mesostasis in ChaXc1 has $\delta^{17}O = +1$‰ and $\delta^{18}O = -5$‰ ($\Delta^{17}O = +4$‰). Fayalitic olivine in chondrule ChaXc1 has $\delta^{17}O = -1$‰ and $\delta^{18}O = -3$‰ ($\Delta^{17}O = +1$‰), resembling the composition of the devitrified mesostasis.

An isolated refractory forsterite (ChaXi1) with a small CL emitting core has $\delta^{17}O = -12$‰ and $\delta^{18}O = -9$‰ ($\Delta^{17}O = -8$‰) in the core and $\delta^{17}O = -15$‰ and $\delta^{18}O = -12$‰ ($\Delta^{17}O = -9$‰) in the fayalite rich rim.

Chondrule Cha1Xc1 is a porphyric Type-IA chondrule surrounded by a thin metal rich rim (~500 µm in diameter). FeO-poor CL emitting forsterite overgrows FeO-rich olivine in the outer part of the chondrule. The refractory forsterite (0.55 wt.% CaO) has $\delta^{17}O = +6‰$ and $\delta^{18}O = +5‰$ ($\Delta^{17}O = +3‰$) and the coexisting fayalitic olivine $\delta^{17}O = +6‰$ and $\delta^{18}O = +15‰$ ($\Delta^{17}O = -2‰$). A single isolated refractory forsterite (ChaXi01) was analysed having $\delta^{17}O = -13‰$ and $\delta^{18}O = -10‰$ ($\Delta^{17}O = -8‰$), typical for ^{16}O-enriched refractory forsterite.

Allende (CV). Chondrules RF07 and RF11 are porphyric Type-IA chondrules. CL emitting cores are present in some of the fayalitic (~18 mol% *fa*) chondrule olivine grains (RF07: 0.72 wt.% CaO, RF11: 0.69 wt.% CaO). The CL emitting forsterite cores have $\delta^{17}O \approx -4‰$, $\delta^{18}O \approx +2‰$ ($\Delta^{17}O \approx -5‰$). Coexisting fayalite in RF07 has $\delta^{17}O = -4‰$ and $\delta^{18}O = +1‰$ similar to CL emitting forsterite.

Two isolated refractory forsterite grains (RF03, RF16, 0.65 wt.% CaO) were measured and have $\delta^{17}O \approx -5‰$ and $\delta^{18}O \approx 0‰$ ($\Delta^{17}O \approx -5‰$) in the CL emitting cores and $\delta^{17}O = -1‰$ and $\delta^{18}O = 0‰$ ($\Delta^{17}O = -1‰$) in the fayalitic rim (RF03, ≈ 15mol% *fa*).

Murchison (C2M). An isolated RF (RF07) with a melt inclusion was measured in Murchison. The forsterite has $\delta^{17}O = 0‰$ and $\delta^{18}O = +1‰$ and the entrapped melt $\delta^{17}O = -4‰$ and $\delta^{18}O = +1‰$ ($\Delta^{17}O \approx -5‰$).

A large isolated forsterite (RF05) is considerably enriched in ^{16}O having $\delta^{17}O = -10‰$ and $\delta^{18}O = -4‰$ ($\Delta^{17}O \approx -8‰$).

Renazzo (C2R). A single forsterite (RF06, 0.49 wt.% CaO) in a porphyric Type-IA chondrule was measured in Renazzo ($\delta^{17}O = +1‰$, $\delta^{18}O = +9‰$, $\Delta^{17}O = -4‰$).

Discussion: In this study we show that the most oxidized chondritic meteorites, the Rumurutiites contain refractory forsterite grains that are identical to those found in carbonaceous and ordinary chondrites. The Dar al Gani 013 forsterites have the same high CaO and Al_2O_3 contents, similarly low FeO contents and a similar enrichment of ^{16}O as RF from other chondrites. This is remarkable because Rumurutiites have the highest $\Delta^{17}O$ of all chondritic meteorites. There is therfore a population of forsterite grains that is common to all chondritic meteorites, independent of their degree of oxidation.

In Fig. 1 is a plot of CaO vs $\Delta^{17}O$ of the forsterite grains analyzed in this study. The apparent decrease in $\Delta^{17}O$ with increasing CaO points to a ^{16}O rich endmember. One possibility is that RF formed by crystallization in early formed refractory-element rich, FeO poor chondrules, with chemical compositions to those found by [11] and with oxygen isotopic compositions resembling those of the most ^{16}O enriched chondrules reported by [12]. As these chondrules decrease in their contents of refractory elements their ^{16}O decreases producing the array of Fig. 1. These refractory chondrules must have been among the first solids formed in the solar nebula (after CAI formation, but pre-dating SiMg-chondrule formation). The various groups of chondritic meteorites formed later. Reducing conditions reflected in RF (see [12]) prevailed during the formation of the first solids in the solar nebula. More oxidized chondritic components formed later at lower temperatures by reaction of early formed metal with with an oxidizing gas/hydrous environment depleted in ^{16}O.

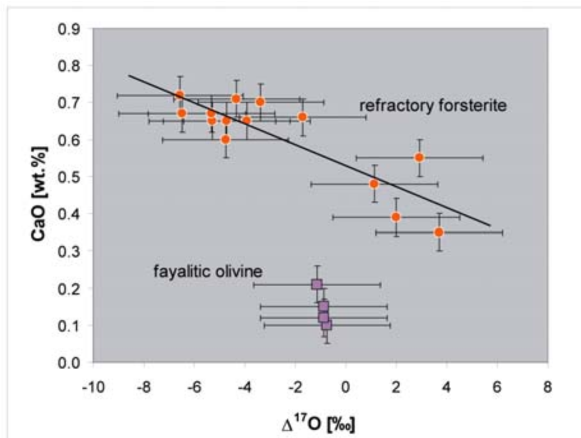

Fig. 1 Plot of CaO in olivine vs. $\Delta^{17}O$, the deviation from the terrestial mass fractionation line. The refractory forsterite samples exhibit a weak anticorrelation between CaO and $\Delta^{17}O$. The samples with CaO < 0.3 wt.% are fayalitic olivine grains.

References:

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