DISCOVERY OF HYDRATED CLASTS WITH VERY HIGH ABUNDANCE OF FERROMAGNESIAN ^{16}O-RICH OLIVINE: INNER OR OUTER SOLAR SYSTEM ORIGIN?

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Introduction: Olivine is one of the major minerals in chondritic meteorites and occurs in all chondritic components, including amoeboid olivine aggregates (AOAs), forsterite-bearing Type B (FoB) Ca,Al-rich inclusions (CAIs), chondrules, and matrices (e.g., [1-4]). As a result, olivines could preserve chemical and isotopic characteristics of their formation environments. There are significant variations in oxygen isotopic compositions of chondritic olivine. Forsteritic olivine in AOAs and FoB-CAIs has solar-like ^{16}O-rich compositions (Δ^{17}O ~ −23±2‰); the former condensed from an ^{16}O-rich gas of ~solar composition, whereas the latter crystallized from remelted condensates in an isotopic similar gaseous reservoir. Olivine phenocrysts in chondrules are significantly ^{16}O-depleted compared to CAIs and AOAs: Δ^{17}O ranges from ~ −7 to +3‰. Only rare relict olivines in chondrules have CAI/AOA-like ^{16}O-rich compositions; these grains most likely represent fragments of CAIs and AOAs incompletely melted during chondrule formation (e.g., [5]). Olivine in matrices of weakly metamorphosed meteorites is extremely fine-grained (<100 nm) and has predominantly forsteritic composition. In metamorphosed chondrites, matrix olivines are coarse-grained (up to 10 µm) and enriched in FeO. Due to small grain sizes, oxygen isotopic compositions of matrix olivines are poorly known. Mapping of matrices of Vigarano [6] and Kakangari [7] using isotope microscopes (secondary ion mass-spectrometer (SIMS) plus SCAPS detector) revealed the presence of ^{16}O-rich olivine grains. While most matrix olivines in Vigarano have ^{16}O-poor compositions, nearly half of olivines measured in Kakangari matrix are ^{16}O-rich. Here, we present for the first time new lithologies largely composed of ^{16}O- and Fe-rich olivine. We attempt to address the question of whether these ^{16}O-rich olivine grains were formed by condensation in the solar nebula or by a secondary process during the evolution of the parent body**.** Mineralogical characteristics of these unusual olivines, as well as *in-situ* measured oxygen-isotope compositions of different phases are reported in detail.

Samples and analytical methods: The new lithologies occur as large clasts in two different ordinary chondrites: Northwest Africa 5206 (LL3) and Northwest Africa 6925 (L3) Scanning electron microscopy (SEM) and electron microprobe analysis (EMPA) were performed at the University of Münster. Two electron-transparent lamellae from one clast were prepared using a Zeiss CrossBeam 340 focused ion beam system (FIB). Subsequent transmission electron microscope (TEM) analyses were performed using an aberration-corrected Thermo Scientific "Themis" (300 kV). *In-situ* oxygen isotope analyses in olivine were carried out using SIMS at both the University of Heidelberg (Cameca ims-1280 HR) and the University of Hawai'i (Cameca ims-1280). *In-situ* trace and rare earth element (REE) concentrations were measured by inductively coupled mass spectrometry by laser ablation (LA-ICP-MS).

Results and discussion: The lithologies consist mainly of FeO-rich olivine ($Fa_{\sim34}$) ranging from a few up to ~20µm, hydrous amphiboles (intergrowth of tremolite and cummingtonite), phyllosilicates, and some Fe-Ni metal and Fe-Ni sulfides. FeO-rich olivine represents the major phase (~60 vol.%) forming the matrix, and commonly occurs as rounded objects (enclosing amphiboles), similar to donut-shaped AOAs with metal or sulfide inside. In addition, fragments of 2 POP chondrules (^{16}O-poor) were found in both clasts. The clasts show flat CI-normalized REE patterns (~1.4 x CI). Oxygen-isotopic compositions in FeO-rich olivine grains plot along ~slope-1 line in 3O-isotope diagram, ranging from ~-25 to ~3‰ in Δ^{17}O; by far most olivines have Δ^{17}O ~-24‰, consistent with typical CAIs and AOAs. Some olivines have positive Δ^{17}O values similar to chondrules in ordinary and R chondrites. The others have intermediate Δ^{17}O values. The ^{16}O-rich and ^{16}O-depleted olivines have similar Fa contents (~34 mol%). The ^{16}O-rich olivines are texturally and isotopically similar to olivines in AOAs and most likely condensed directly in the early solar nebula at high temperatures. Subsequently they accreted together with less ^{16}O-rich olivines and water ices (as indicated by abundant hydrated phases), and experienced Fe-Mg interexchange during fluid-assisted thermal metamorphism in an asteroidal setting but largely escaped from O-isotope equilibration. The extremely high proportion of ^{16}O-rich condensates in the clasts may suggest their early accretion either in the inner or outer disk. Bulk Cr and Ti isotopic compositions of the clasts may help to understand their genetic relationship to carbonaceous or noncarbonaceous meteorites. This work is in progress.

References: [1] Zolensky & Ivanov (2003) *Chemie der Erde* 63:185–246; [2] Krot et al. (2004) *Meteorit. Planet. Sci.* 39:1931–1955.; [3] Doyle et al. (2015) *Nature Comm.* 6:1–10; [4] Dobrica et al. (2022) *Meteorit. Planet. Sci.* 57:381-391. [5] Marrocchi et al. (2018) *Earth Planet. Sci. Lett* 496:132-141; [6] Kunihiro et al. (2005). *Geochim. Cosmochim. Acta* 69:763-773. [7] Nagashima et al. (2015) *Geochim. Cosmochim. Acta* 151:49–67.