

FIRST Ti-XANES ANALYSES OF OLIVINE IN AMOEBOID OLIVINE AGGREGATES

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Introduction: Amoeboid olivine aggregates (AOAs) [1] are a common type of inclusion in many carbonaceous chondrite groups [2]. They have long been interpreted as nebular condensates [1, 2]. Their primary phases are very ¹⁶O-rich [3], indicating formation in a solar gas. We measured the valence of Ti in olivine in two AOAs (a) to see if they contain Ti³⁺, the presence of which would suggest formation in a highly reducing environment, such as a solar gas, strengthening the evidence for origin in the early nebula; and (b) for comparison with our results for chondrule olivine [4].

Methods: Selected areas in two AOAs, TS19F2 (Allende, oxidized CV3) and Ef2 (Efremovka, reduced CV3), were documented by SEM and analyzed by electron probe. The AOAs mainly consist of rounded lumps of fine (~4-25 μm) olivine grains with FeO-rich edges (TS19F2) and interstitial Al-diopside and anorthite (both). Titanium K XANES (X-ray absorption near edge structure) spectra were collected using the GSECARS X-ray microprobe in fluorescence mode, with a 3 μm X-ray beam, and valences were derived as before [4, 5].

Results: The olivine in both samples contains significant proportions of Ti³⁺. Our 20 analyses of TS19F2 olivine yield Ti valences from 3.19 to 3.63 (±0.08) and average 3.45±0.12 (1σ). In a 16-point linear traverse, six spots at least partially sampled Fe-, Al-bearing interstitial material. These analyses average 3.52±0.05, so its Ti is not significantly oxidized compared to the stoichiometric olivine we analyzed. For Ef2 the range for 8 olivine analyses is 3.52-3.85 and the average is 3.69±0.10. There is no correlation with fayalite content. Ef2 olivine is more forsteritic (Fa_{0.5}) than that in TS19F2 (Fa₅₋₃₂) but its Ti is more oxidized. The latter sample is highly unequilibrated, with a wider range of both olivine composition and Ti valence than Ef2.

Discussion: The oxidation state of Ti in AOAs preserves a record of their origin in a reducing environment. The calculated Ti₂O₃/TiO₂ buffer curve for the pure oxides is ≥4 log units below IW, so Ti³⁺ and Fe²⁺ should not coexist. As in chondrule olivine [4], the oxidation states of Ti and Fe in AOA olivine do not reflect the same *f*_{O₂}. These observations can be understood if AOAs and chondrule precursor assemblages formed under reducing conditions and subsequently were exposed to relatively oxidizing conditions, and if, in olivine, Fe equilibrates with changing *f*_{O₂} more rapidly than does Ti. Assuming the AOAs we analyzed were never molten, the present results suggest that a molten stage is not required for enhanced oxidation of Fe relative to Ti in olivine. It has been suggested [2] that some AOAs melted and formed chondrules; the presence of Ti³⁺ in both chondrule and AOA olivine is consistent with a common source, or perhaps related precursor assemblages, for these objects.

Conclusion: The Ti valences and O-isotopic compositions [3] of olivine in AOAs are consistent with formation of these objects in a reducing, ¹⁶O-rich environment, such as a solar gas.

References: [1] Grossman L. and Steele I. M. 1976. *Geochimica et Cosmochimica Acta* 40:149–155. [2] Krot A. N. et al. 2004. *Chemie der Erde* 64:185-239. [3] Yurimoto H. et al. 2008. *Reviews in Mineralogy & Geochemistry* 68:141-186. [4] Simon S. B. et al. 2008. Abstract #1352. 39th Lunar and Planetary Science Conference. [5] Simon S. B. et al. 2007. *Geochimica et Cosmochimica Acta* 71:3098–3118.