MANGANESE-RICH OLIVINE IN AOAS: IMPLICATIONS FOR FORMATION AND ALTERATION CONDITIONS. M. Komatsu[1], T. J. Fagan[1], and T. Mikouchi[2]. [1]Department of Earth Sciences, Waseda University, Tokyo, Japan 169-8050 (komatsu@aoni.waseda.jp), [2]Department of Earth and Planetary Science, University of Tokyo.

Introduction:

Amoeboid olivine aggregates (AOAs) are irregularly shaped, fine-grained objects that constitute a few volume-percent of meteorites in most carbonaceous chondrite groups. They are mainly composed of olivine, Fe,Ni-metal and refractory Ca-Al-rich minerals such as Al-diopside, anorthite, ± spinel, ± melilite, Al-Ti-diopside. Mineralogy and chemical compositions of AOAs are similar to those predicted by equilibrium thermodynamic condensation models [e.g., 1, 2], suggesting that AOAs formed primarily by gas-solid condensation [3].

It has also been shown that some AOAs contain olivines with Mn-rich compositions similar to low-iron Mn-enriched (LIME) olivine, which was identified originally in IDPs [4]. LIME silicates have wt % MnO/FeO >0.1, and usually <1.0 wt.% FeO, and are interpreted as condensates that preserve the redox state of solar nebula gas [5]. The MnO/FeO ratio of Mn-rich olivine in AOAs is not as high as in LIME olivine, but it is likely that the formation of Mn-rich olivine is related to LIME olivine. Mn-rich olivine in AOAs have been described only in AOAs from CR chondrites [6], and Y-81020 (CO3.0) and Acfer 094 (ungrouped carbonaceous) [7]. In this study, we focus on Mn-rich olivines as indicators of formation and alteration conditions of AOAs.

Samples:

Polished thin sections of the ungrouped carbonaceous chondrite NWA 1152 and the CO chondrite Y-81020 were studied using optical microscopy, SEM, and JEOL JX-8900 University of Tokyo and Waseda University. Textures and chemical compositions were compared to AOAs from reduced CV chondrites [8], oxidized CV chondrite Y-86009 and Allende [9], and CO chondrites [10].

Results and Discussion:

Mineralogy of NWA 1152 AOAs.

The AOAs are irregularly shaped, 150μm to 1mm across in thin section, and consist of aggregates of fine-grained olivine, Al-diopside, spinel, and blebs of FeNi metal and magnetite (Fig. 1). No phyllosilicates were observed. These AOAs are texturally similar to those in reduced CV chondrites [11] and CR chondrites [6].

Most of the olivine grains in NWA 1152 AOAs are near pure forsterite ($Fo_{96\text{-}99}$, Fig. 3). Previous studies have correlated Fe-enrichment in AOA olivine with petrologic subtype of a host meteorite [10,11]. The low Fa-contents of most olivine in NWA 1152 AOAs suggest that primary compositions are preserved.

Alteration characteristics of AOAs and relation to Mn-rich olivine

Petrology

Y-81020 (CO3.0) is considered to be one of the most primitive chondrites [12]. Secondary alteration is very minor (Fig.3a).

The CV chondrites are subdivided into the reduced (CVred) and two oxidized subgroups, Allende-like (CVoxA) and Bali-like (CVoxB) chondrites [13]. The CVoxB (e.g., Kaba, Bali) experienced hydrous alteration that resulting in formation of phyllosilicates, magnetite, fayalite, andradite, and salite-hedenbergite pyroxenes (Fig. 3b) [1]. On the other hand, the CVoxA (e.g., Allende) experienced alteration under different conditions resulting in formation of nepheline, sodalite, andradite, salite-hedenbergite pyroxenes, fayalitic olivine, and zoning toward Fe-rich rims in primary olivines (Fig.3c). The reduced CV chondrites experienced alteration similar to that of CVoxA, but of a smaller degree (Fig.3d).

Chemical compositions

Mn-rich olivine is observed in AOAs from Y-81020 and Y-86009. In the NWA 1152 AOAs, several olivine analyses show enrichments in MnO, with MnO/FeO approaching 1.0 (Fig. 4). These compositions are similar to LIME olivine.

Thermodynamic models show that LIME-like olivine in AOAs can form by gas-solid reactions as temperature declines to near 1100 K [1,2]. The model of Ebel et al [7] indicates that Mn-rich, Fe-poor olivine forms under relatively low oxygen fugacities (solar composition, no dust enrichment).

When the Mn-rich olivine is present in AOAs, it generally occurs at the edges of the inclusion. This is consistent with the condensation calculation that predicts Mn-enrichment with decreasing temperature [7]. Although Mn-rich olivine is observed in Y-86009 CVoxB, it is not observed in reduced CV chondrites and Allende. These two types of meteorites experienced some (reduced CV) and high degree (Allende) of thermal alteration.

It has been also shown that the rimmed AOAs which experienced annealing after aggregation tend to have lower Mn contents [7]. This is consistent with our prediction that Mn was lost by heating.

It is likely that Mn-rich olivine was originally present in many AOAs as a primary phase, and then lost during the thermal processing. Therefore, Mn-rich olivine in AOAs can be a sensitive indicator for the thermal processes such as annealing in the solar nebula [7] and parent body thermal alteration.

References: [1] Ebel D. (2006) *Meteorites and the Early Solar System II.* 253-277. [2] Davis A. M. and Richter F. M. (2007) *Treatise on Geochemistry 1,* 407–430. [3] Fagan T. J. et al. (2004) *MaPS* 39, 1257-1272. [4] Klöck W. et al. 1989. *Nature* 339: 126-128. [5] Ebel D. S. et al. 2012. *MaPS* 47:585-593. [6] Weisberg M. K. and Connolly Jr. H. C. 2008. *Lunar Planet. Sci. Conf. 37,* #1981. [7] Sugiura N. et al. 2009. *MaPS* 44:559-572. [8] Komatsu M. et al. 2001. *MaPS* 36:629-641. [9] Komatsu M. et al., 2006. *Lunar Planet. Sci. Conf. 39,* #1523. [10] Chizmadia L. et al. 2002. *MaPS* 37:1781-1796. [11] Krot A. N. et al. 2004. *Chemie der Erde* 64:185–239. [12] Kimura M. et al. 2008. *MaPS* 43:1161-1177. [13] Krot A. N. et al., 1998. *MaPS* 33:623-645. [14] Zolensky M. E. et al. 2006. *Science* 314: 1735-1753.

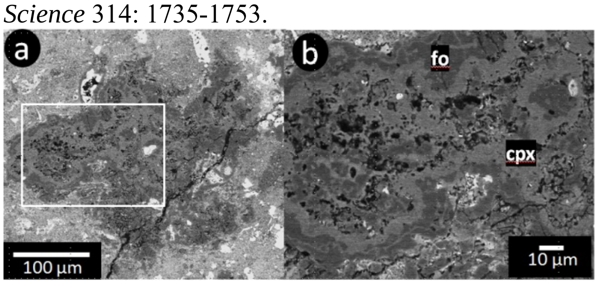

Fig. 1. BSE image of an AOA in NWA 1152. It consist of aggregates of fine-grained olivine (fo), Al-diopside (cpx), spinel, and blebs of FeNi metal/magnetite. No phyllosilicates were observed.

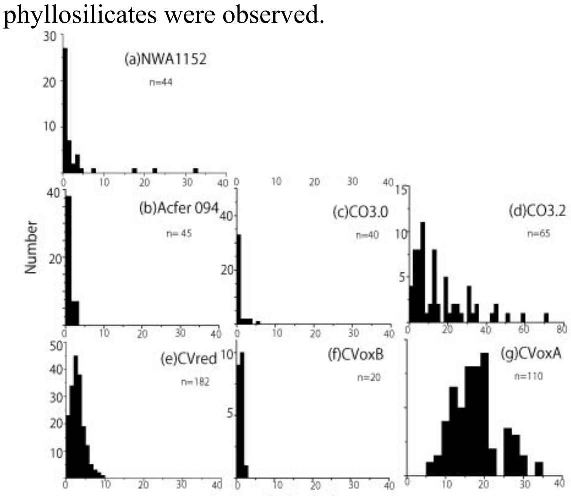

Fig. 2. Compositions of olivine in AOAs in NWA 1152 (a), (b) Acfer 094 [11], (c) Y-81020 (CO3.0), (d) Y-82050 and Rainbow (CO3.2) [10], (e) Efremovka, Leoville, Vigarano (CVred) [12], (f) Kaba (CVoxB) [13], and (g) Allende (CVoxA).

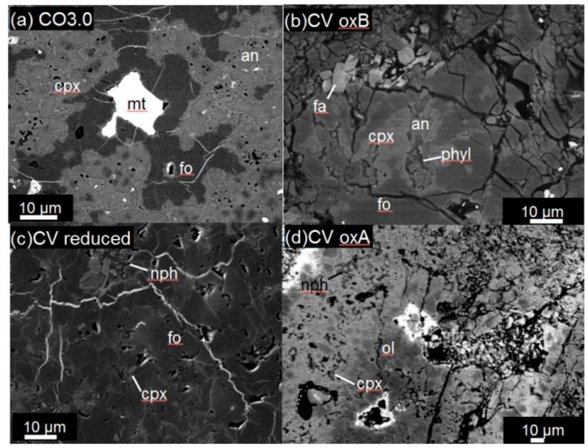

Fig. 3. BSE images of Y-81020 (CO3.0;a), Y-86009 (Bali-type oxidized CV; b), Leoville (reduced CV, c), and Allende (Allende type oxidized CV, d). an=anorthite, fa=fayalite, phyl=phyllosilicate, nph=nepheline, mt=Fe,Ni-metal.

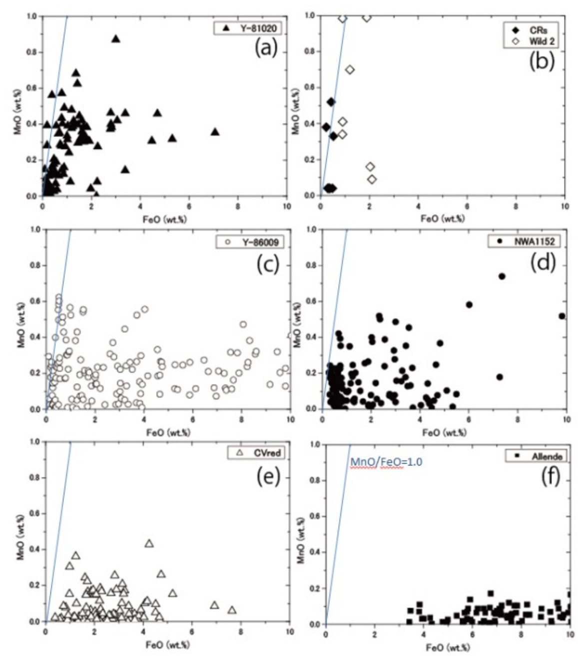

Fig. 4. Plot of FeO versus MnO for olivine in AOAs in Y-81020 (a; CO3.0), AOAs from CR chondrites [6] and Wild 2 cometary particles [14] (b), AOAs from Y-86009 (c; Bali-type oxided CV [9]), AOAs from NWA 1152 (d; ungrouped), AOAs from Efremovka and Leoville (e; reduced CV [8]), and AOAs from Allende (f; Allende-type oxidized CV).