AMOEBOID OLIVINE AGGREGATES AND AOA-BEARING CHONDRULE FROM Y-81020 CO3.0 CHONDRITE: DISTRIBUTIONS OF OXYGEN AND MAGNESIUM ISOTOPES. S.Itoh\textsuperscript{1}, A.E. Rubin\textsuperscript{2}, H. Kojima\textsuperscript{3}, J. T. Wasson\textsuperscript{4} and H. Yurimoto\textsuperscript{5}.\textsuperscript{1} LPS, Department of Earth and Planetary Science, Tokyo Institute of Technology, Meguro-Ku, Tokyo 152-8551, Japan (sito@geo.titech.ac.jp), \textsuperscript{2} Institute of Geophysics and Planetary Physics, University of California, Los Angeles CA 90095-1567, USA. \textsuperscript{3} National Institute of Polar Research, Kaga, Itabashi-Ku, Tokyo 173-8515 Japan

Introduction: Amoeboid olivine aggregates (AOAs) were believed as kind of refractory inclusions. AOAs formed in the similar environment of CAI-forming region in solar nebula. However, it is not sufficient to determine the AOA-forming timescale comparing with CAI-forming timescale with Al-Mg systems. In addition, although many studies showed chondrule formed ~2Ma after CAI-formation from Al-Mg systems \cite{1,2,3}, it is not clear the forming relationships between AOAs and chondrules in spite of consistent with major phases for each other. Chemical and isotopic compositions of AOAs and chondrules have been disturbed by aqueous alteration or thermal metamorphism in solar nebula and parent body \cite{4,5}. Many studies pointed out that Y-81020 CO3.0 chondrite is the most pristine in CO3 chondrites from petrological and isotopic studies of fine-grained Ca-Al-rich inclusions (CAIs), AOAs, chondrules and matrix \cite{6,7,8}.

In order to establish the genetic relationships between CAIs, AOAs, and chondrules in the early solar system precisely, we presents the relationships between petrologic, chemical, oxygen and Al-Mg isotopic compositions for individual crystals in AOAs and AOA-bearing chondrule from Y-81020 CO chondrites.

Analytical Techniques: 50 fine-grained AOAs and one AOA-bearing chondrule were found from two thin sections (#61-1 and #56-4 from National Institute of Polar Research in Tokyo) of Yamato-81020 CO 3.0 chondrites. They were examined with a petrographic microscope and by X-ray microanalysis (using JEOL 5310LV scanning electron microscope at TiTech; Leo 1430 VP-EDX scanning electron microscope and the Cameca CAMEBAX electron microprobe at UCLA).

In-situ oxygen and magnesium isotope analyses were performed by the TiTech Cameca ims-1270 SIMS instrument. A 20keV Cs\textsuperscript{+} primary ion beam for oxygen analysis focussed to a 2~5\textmu m spot, and for Mg isotope analysis, a O primary ion beam focused to 2~5\textmu m. Oxygen isotopes were measured as negative secondary ions with M/AM of ~6000 and Mg-Al isotopes were measured as positive secondary ions with M/AM of ~4000. Other analytical conditions for O and Mg isotope analysis have been described elsewhere \cite{9,10}. We carefully evaluated overlapping of primary beam among mineral phases by scanning electron microscope after SIMS analysis. (e.g. Data from multi-phases were not used in this study. Such analyses apparently show intermediate O isotopic values as analytical artifact.)

Results: The AOAs from Y-81020 have similar size distributions of fine-grained CAIs from the same thin section \cite{1}: The AOAs were irregularly shaped and 40-400\textmu m across in size, composed of forsterite (FO\textsuperscript{98-100}) and Ca-Al-rich components consisting with Al-Ti-rich diopside, diopside, anorthite and rarely spinel. Each AOA has no alteration minerals and fayalitic olivine. The petrography indicates that the AOAs have not been altered or metamorphosed. Quantities of refractory components, i.e., CAI-regions in AOAs are continuously distributed from 0\% to 100\% as modal proportions. Therefore, AOAs enriched in CAI-region are equal to olivine-rich CAIs. The CAI-region often distributes heterogeneously within an AOA. We selected AOAs with 80vol\% CAI-region (AOA11), with 50vol\% (AOA2), with 20vol\% (AOA4) and with heterogeneous CAI-region (AOA15) for isotopic microanalyses.

AOA-bearing chondrule (AOA13) are ovoid shaped and ~ 350\textmu m across in size. AOA-region (~150\textmu m) of AOA13 is enclosed completely in the chondrule and composed of forsterite (FO\textsuperscript{98-100}) and anorthite and diopside enclosed by enstatite. The AOA-region has corroded texture seeming as relict phases. The surrounding area of AOA13 consists of pigeonite enclosed by diopside, diopside, lath anorthite (Na\textsubscript{2}O\textsuperscript{O}~1.5wt\% FeO = ~0.5wt\%) and Fe-Ni metal. This chondrule could be classified to Ca-Al-rich chondrule with chemical compositions \cite{11}.

The mesostasis consists of mixture of anorthite (~2\textmu m), diopside (1-5\textmu m), pigeonite (~2\textmu m) and cavities. Each crystal except AOA-region shows dendritic and the mesostasis is highly porous.

O-isotopic compositions of each phase in AOAs and in the AOA-bearing chondrule are shown in Fig.1. All of the primary phases (spinell, diopside, anorthite, and olivine) of AOAs are enriched in $^{18}\text{O}$ ($\delta^{17,18}\text{O}_{\text{ANSM}}$ ~ $-40\%$). Anorthite and diopside grains in AOA4 and in depleted CAI-region of AOA15 could not be measured O isotopic compositions due to the small grain size (~2\textmu m). However, the result of
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overlapping analysis from anorthite (80%) / diopside (20%) in AOA4 suggests these phases have the same O isotopic composition of other AOA phases (δ17,18O_{SMOW}= -40‰). We conclude O isotopic compositions of primary phases in AOA are enriched in 16O despite of the wide variation of CAI abundance.

For AOA-bearing chondrule, Olivine grains are enriched in 16O about the same compositions of other AOAs from Y-81020. This is consistent to the textural observation. In contrast, anorthite and pigeonite surrounding the AOA-region are depleted in 16O.

Al-Mg isotope system of three AOAs (AOA11, AOA2, and AOA15) and AOA-bearing chondrule (AOA13) are shown in Fig.2. The all data were obtained from anorthite grains. These AOAs have the radiogenic 26Mg with initial 27Al/26Al of (2.7±0.7) x 10^{-5} (AOA11), (2.9±1.5) x 10^{-5} (AOA2), and (3.2±1.5) x 10^{-5} (AOA15), respectively. In contrast, no radiogenic 26Mg were detected for AOA-bearing chondrule.

Discussion: O isotopic compositions of AOAs from Y-81020 are consistent with those of fine-grained CAIs from Y-81020 [1]. With respect to the O isotopic results of fine-grained refractory inclusions (AOAs and CAIs) from Y-81020 were formed from the same reservoir in the early solar system. As a results, we conclude that 16O-rich components are dominant in the forming region of fine-grained refractory inclusion in the solar nebula. AOA-bearing chondrule (AOA13) from Y-81020 contains 16O-rich forsterite grains of AOAs. Some studies reported O isotopic compositions of olivine in Al-rich chondrules were slightly enriched in 16O relative to the bulk chondrule value [12]. Our results could be attributed that one reason of variations of 16O-enrichment among chondrules is due to containing AOAs in chondrule precursors.

All AOAs from Y-81020 shows smaller radiogenic 26Mg excess comparing with the canonical value (27Al / 26Al = 5 x 10^{-5}). If these difference is due to time difference, the relative age of AOAs after CAI formation is from 0.48 to 0.08Ma. Alternatively, the differences of initial value indicate spatial heterogeneity of 26Al in 16O-rich reservoir. The absence of detectable radiogenic 26Mg and 16O-enrichment in AOA-bearing chondrule suggests that chondrule and AOA forming-regions were not in the same place and time.