

OXYGEN ISOTOPES IN AMMS AND IDPS: UNIVERSALITY OF OXYGEN ISOTOPE SYSTEMATICS OF CRYSTALLINE SILICATES IN COMETS. D. Nakashima¹, S. Shimizu¹, R. Oike¹, K. Fukuda², M. Zhang², N.T. Kita², M.E. Zolensky³, J.I. Lee⁴, S. Park⁴, and T. Nakamura¹. ¹Dept. Earth Sci., Tohoku Univ., Miyagi 980-8578, Japan (dnaka@tohoku.ac.jp), ²WiscSIMS, Dept. Geosci., Univ. of Wisconsin-Madison, WI 53706, ³ARES, NASA Johnson Space Center, Houston, TX 77058, ⁴Korea Polar Research Institute (KOPRI), Incheon 21990, Korea.

Introduction: It has been suggested that the major source of crystalline silicates in comets is CR chondrule-like materials along with minor sources including O, R, CH-CB chondrite chondrule-like materials based on the comparisons of oxygen isotope systematics between cometary silicates and chondrules from various types of primitive chondrites [1-3]. However, cometary silicates used for these studies are from two comets: Wild2 and a parent comet of the giant cluster interplanetary dust particle (GC-IDP) U2-20GCA. To explore whether crystalline silicates in all comets have similar oxygen isotope systematics, other materials of likely cometary origin, such as anhydrous IDPs and ultracarbonaceous Antarctic micrometeorites (UCAMMs), are needed to be measured for oxygen isotopes.

Anhydrous IDPs are believed to be cometary in origin and are characterized by GEMS (glass embedded with metal and sulfide; [e.g., 4]). Among the AMMs, ultracarbonaceous AMMs and AMMs bearing GEMS are also believed to be cometary in origin [e.g., 5-6]. Oxygen isotope systematics of randomly sampled cometary AMMs and anhydrous IDPs may represent that of crystalline silicates in all comets. Here we report oxygen isotope analysis of three AMMs and one anhydrous IDP using the IMS 1280 ion microprobe at the WiscSIMS laboratory and compare the oxygen isotope systematics with those of Wild2 particles and the GC-IDP U2-20GCA.

Samples and methods: AMMs were recovered from surface snow at Victoria Land in 2014 and 2016. L2008AC13 was collected in 1989. After synchrotron radiation X-ray diffraction analysis, they were embedded in epoxy and ultramicrotomed, which were examined using TEM at Tohoku University. Potted butts were analyzed using FE-SEM at Tohoku University. The oxygen isotope analyses were made using 1×2µm Cs⁺ primary beam under the conditions similar to those in [e.g., 3].

Results: Backscattered electron (BSE) images of the AMMs and IDP are shown in Fig. 1. ROP5E10 is an unmelted AMM similar to type-II chondrules and consists of FeO-rich olivine (Fo₆₀), pyrrhotite, and interstitial glass (Fig. 1a). The AMM is surrounded by a magnetite rim, a product of atmospheric entry. SSP4J8 is an unmelted AMM similar to anhydrous IDPs and consists of olivine, pyroxene, and troilite along with GEMS, LIME olivine, and KOOL grains (Kosmochloric augite

+ FeO-rich olivine; [7]) (Figs. 1b-d). The Mg# of olivine and pyroxene range from 65 to 97. SSP4M9 is a scoriaeous AMM composed of low-Ca pyroxene of En₉₈Wo_{0.6}, high-Ca pyroxene of En₇₇Wo₂₀, and plagioclase of An₉₃Ab₇, which is surrounded by fine-grained matrix (Fig. 1e). Given the high concentration of carbon (higher than SSP4J8; detected by FE-SEM/EDS), SSP4M9 is possibly an ultracarbonaceous AMM. L2008AC13 is an anhydrous IDP composed of low-Ca pyroxene of En₉₀Wo₆₅ and Fe-sulfide (Fig. 1f).

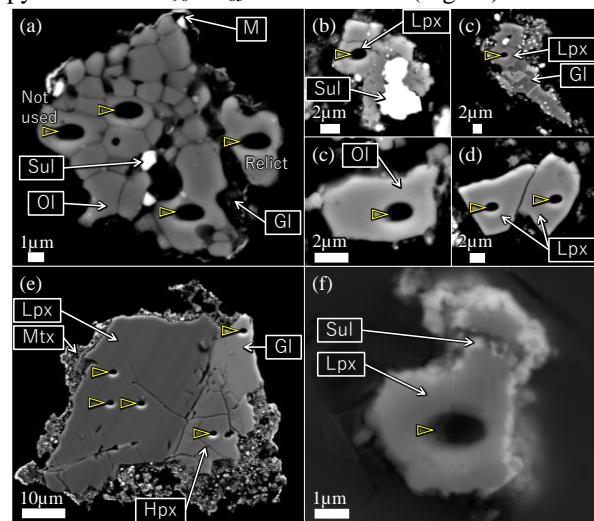


Fig. 1: BSE images of ROP5E10 (a), SSP4J8 (b) – (d), SSP4M9 (e), and L2008AC13 (f). Analysis points are shown by the vertex of an open triangle. Abbreviations: M, magnetite; Sul, Fe-sulfide; Ol, olivine; Gl, glass; Lpx, low-Ca pyroxene; Hpx, high-Ca pyroxene; Mtx, fine-grained matrix.

The results of oxygen isotope analyses are shown in Fig. 2. The oxygen isotope ratios plot along the PCM line with $\Delta^{17}\text{O}$ values from -16‰ to $+1.2\text{‰}$, though mostly clustering around 0‰ . The $\Delta^{17}\text{O}$ value of -16‰ is from the type-II chondrule-like AMM ROP5E10, of which other two $\Delta^{17}\text{O}$ values are -0.3‰ and $+0.4\text{‰}$. It is considered that the olivine grain with $\Delta^{17}\text{O}$ of -16‰ is relict, which are excluded from the average oxygen isotope ratios. The $\Delta^{17}\text{O}$ values and Mg# of SSP4J8 are variable from -2.6‰ to $+1.2\text{‰}$ and from 78 to 95, respectively. Therefore the, average $\Delta^{17}\text{O}$ value and Mg# are not calculated for the AMM. Oxygen Isotope ratios of SSP4M9 are reproducible within analytical uncertainties, and the average and 2SE of $\Delta^{17}\text{O}$ values of five

analyses are $-3.3 \pm 1.0\%$. One spot analysis was made on L2008AC13, of which $\Delta^{17}\text{O}$ value is -1.7% .

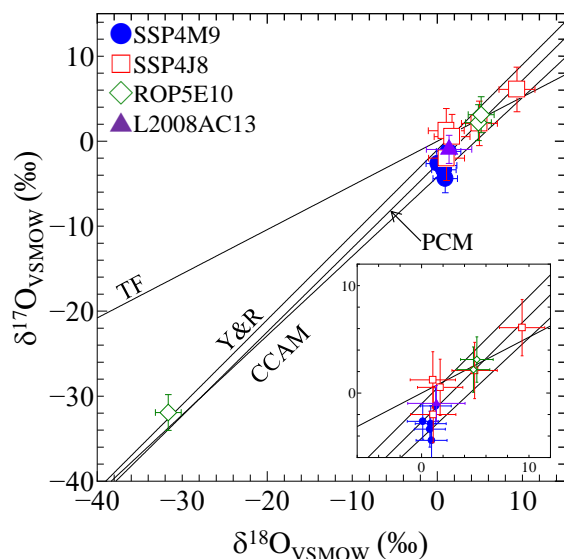


Fig. 2: Oxygen isotope ratios of three AMMs and an anhydrous IDP of this study. TF, Y&R, PCM, and CCAM represent the terrestrial fractionation line, the Young and Russell line [8], the Primitive Chondrule Mineral line [9], and the Carbonaceous Chondrite Anhydrous Mineral line [10].

Discussion: The AMM SSP4J8 with variable Mg# and $\Delta^{17}\text{O}$ values is mineralogically and chemically very similar to anhydrous IDPs except for its large size ($\sim 100 \mu\text{m}$ in size). Since similar Mg# and $\Delta^{17}\text{O}$ variations, LIME olivine, KOOL grains are observed in Wild2 particles from track 77 [1,7], the original impactor may have been like the AMM SSP4J8.

Fig. 3a compares Mg# and average $\Delta^{17}\text{O}$ values of AMMs and IDPs in this study and previous studies [6, 11-12]. We found samples with $\text{Mg}\# > 90$ tend to have negative $\Delta^{17}\text{O}$ values with an average of $-2.1 \pm 3.4\%$ (2SD), and those with $\text{Mg}\# < 90$ have variable $\Delta^{17}\text{O}$ values from -2.6% to $+2.7\%$. Thus, the AMMs and IDPs seem to have a negative $\Delta^{17}\text{O}$ -Mg# correlation. Similar correlations are also observed for GC-IDP U2-20GCA and Wild2 particles (Figs. 3b-c). For the GC-IDP, the average $\Delta^{17}\text{O}$ value of FeO-poor particles is $-1.5 \pm 3.5\%$, and $\Delta^{17}\text{O}$ variation of FeO-rich ones is from -2.8% to $+3.4\%$. For Wild2 particles, the average $\Delta^{17}\text{O}$ value of FeO-poor particles is $-2.2 \pm 4.4\%$, and $\Delta^{17}\text{O}$ variation of FeO-rich ones is from -3.8% to $+2.5\%$. Thus, the oxygen isotope systematics of randomly sampled cometary AMMs and anhydrous IDPs, which derive from various comets, is similar to those of crystalline silicates from single comets like Wild2 and the parent comet of GC-IDP U2-20GCA. Although the number of data from AMMs and IDPs is very limited, it is proposed that every comet has a common oxygen isotope systematics similar to that of CR chondrite chondrules [1-3].

References: [1] Nakashima D. et al. (2012a) *EPSL*, 357-358, 355-365. [2] Defouilloy C. et al. (2017) *EPSL*, 465, 145-154. [3] Zhang M. et al. (2021) *EPSL*, 564, 116928. [4] Keller L.P. and Messenger S. (2011) *GCA*, 75, 533-5365. [5] Nakamura T. et al. (2005) *MAPS*, 40, A110. [6] Noguchi T. et al. (2019) *LPSC L*, # 2392. [7] Joswiak D.J. et al. (2009) *MAPS*, 44, 1561-1588. [8] Young E.D. and Russell S.S. (1998) *Science*, 282, 1874-1877. [9] Clayton R.N. et al. (1977) *EPSL*, 34, 209-224. [10] Ushikubo T. et al. (2012) *GCA*, 90, 242-264. [11] Aléon J. et al. (2009) *GCA*, 73, 4558-4575. [12] Nakashima D. et al. (2012b) *MAPS*, 47, 197-208.

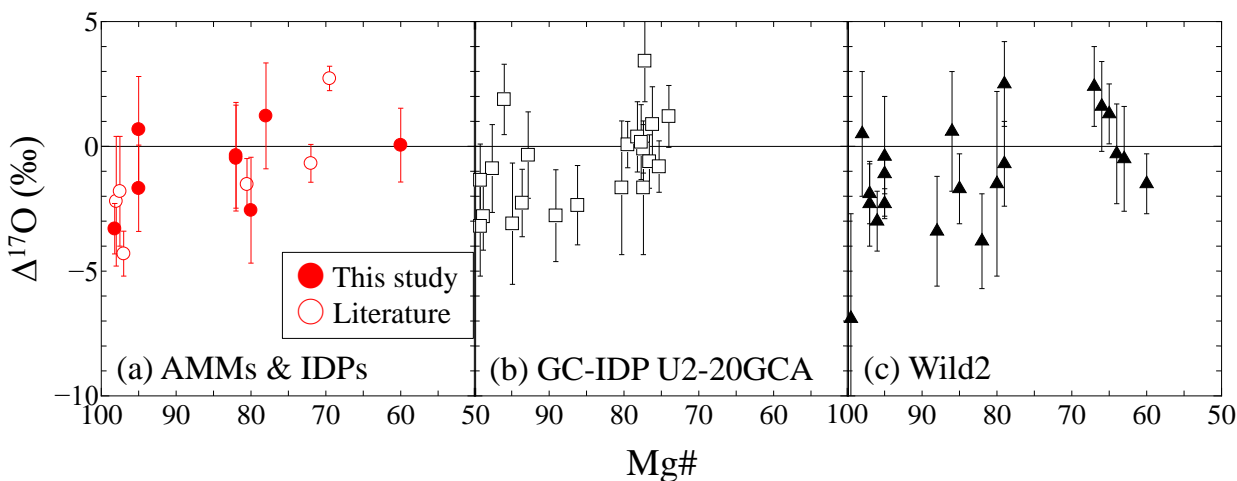


Fig. 3: Comparison of $\Delta^{17}\text{O}$ values and Mg#'s for cometary AMMs and anhydrous IDPs (a), GC-IDP U2-20GCA (b), and Wild2 particles (c). The $\Delta^{17}\text{O}$ values and Mg# of GC-IDP U2-20GCA and Wild2 particles are from [1-3].