HIGH PRECISION OXYGEN THREE-ISOTOPE ANALYSIS OF CRYSTALLINE SILICATES OF COMET WILD 2: A GENETIC LINK TO CHONDRULES AND AOAS IN CR CHONDRITES. D. Nakashima[1], T. Ushikubo[1], D. J. Joswiak[2], D. E. Brownlee[2], G. Matrajt[2], and N. T. Kita[1]. [1]WiscSIMS, Dept. Geoscience, University of Wisconsin-Madison, Madison, WI 53706 (naka@geology.wisc.edu), [2]Dept. Astronomy, University of Washington, Seattle, WA 98195.

Introduction: One of the major discoveries from the Stardust mission [1] is the observation of crystalline silicate particles that resemble Ca, Al-rich inclusions (CAIs) and chondrules in carbonaceous chondrites [2-3]. The previous studies showed that the ferromagnesian silicate particles from Wild 2 and anhydrous interplanetary dust particles have oxygen isotope ratios very similar to those in chondrules in carbonaceous chondrites [2-9]. However, the total number of Wild 2 particles that were analyzed for oxygen isotopes with sufficient precisions (±1-2‰) is still limited (n=11; [2-6]) for further comparison. Here we report oxygen isotope analyses of 8 additional particles from Wild 2 using a Secondary Ion Mass Spectrometer (SIMS) and further discuss a genetic link to chondrules in various types of carbonaceous chondrites.

Analytical Methods: We prepared six Wild 2 particle mounts. The particles were embedded in an 8mm Al-disk using indium with San Carlos olivine standard grains [10]. The oxygen isotope analyses were made using 1×2μm Cs^+ primary beam under the conditions similar to those in [8,11]. For precise aiming of SIMS analysis spots in the tiny particles, we removed 1μm^2 area of the surface palladium and carbon coating by focused ion beam (FIB) and identified the location by the $^{16}O^-$ ion imaging prior to a SIMS spot analysis [10].

Samples: Six out of eight Wild 2 particles were extracted from a single Stardust track (77), which consist of ferromagnesian particles with various Mg#'s including Mn-rich forsterites (detailed chemistry is reported in [12-13]). Other two particles (FeO-rich olivine with glass and Mn-rich fortsterite) were from tracks 22 and 57. Sizes of the particles range from 2 to 7μm.

Results: The result of oxygen isotope analyses of Wild 2 particles are shown in Fig. 1. Data from three Mn-rich forsterites (fragments 6 and 50 from track 77 and fragment 10 from track 57) plot far below the Terrestrial Fractionation (TF) line with $\delta^{18}O$, $\delta^{17}O$ ~ −50‰, similar to CAIs. Their $\Delta^{17}O$ (=$\delta^{17}O-0.52\times\delta^{18}O$) values are ~ −23‰. Data from fragment 10 from track 57 plot on the left side of the CCAM (Carbonaceous Chondrite Anhydrous Mineral) line towards lower $\delta^{18}O$ (Fig. 1), which may be due to instrumental fractionation caused by a minor beam overlap with surrounding acrylic resin [2]. The other five ferromagnesian particles show oxygen isotope ratios that plot around the TF line (Fig. 1). Data from the FeO-rich olivine particles, excluding data of fragment 4 from track 77 and one of two analyses from fragment 7 from track 22, plot above the TF line. Data from fragment 9 from track 77 (FeO-poor augite) plot below the TF line.

Discussion: Three Mn-rich forsterite particles show ^{16}O-rich oxygen isotope ratios. In CR chondrites, amoeboid olivine aggregates (AOAs), which are ^{16}O-rich, contain Mn-rich forsterites [e.g., 14]. There may be a genetic link between Mn-rich forsterite Wild 2 particles and CR-AOAs. They are possibly condensates from an ^{16}O-rich gaseous reservoir, considering that Mn-rich forsterite was suggested to have been a condensate from a solar nebular gas [15].

Six particles that were extracted from the single Stardust track 77 have various chemical compositions with a wide range of $\Delta^{17}O$ values from ~ −23‰ to +2.4‰. The original aggregate (>6μm; [16]) of these particles should have diverse oxygen isotope and chemical heterogeneities at the μm-scale, suggesting that the Wild 2 particles largely escaped from parent body processes including thermal metamorphism.

Four FeO-rich particles show the $\Delta^{17}O$ range from −1.5‰ to +2.4‰, while the FeO-poor augite particle has a $\Delta^{17}O$ value of −3.1‰. Two FeO-poor particles (Pyxie from track 81 and Bidi from track 130) showed $\Delta^{17}O$ values of −1.2‰ and −1.9‰ [5]. Combined with the results of previous Wild 2 particle studies [2-6], the FeO-poor particles cluster at −2‰ in $\Delta^{17}O$, while FeO-rich particles have $\Delta^{17}O$ values from −4‰ to +2.4‰ (Fig. 2a). The systematic trend between Mg# and $\Delta^{17}O$ values was not observed in chondrules in ordinary and enstatite chondrites [17-18] but those in carbonaceous chondrites, e.g., Acfer 094 (ungrouped): bimodal $\Delta^{17}O$ values of –5‰ and –2‰ for type I and type II chondrules, respectively (Fig. 2b; [19]). Similar bimodal distributions were observed in CV3 and CO3 chondrites [20-21]. Chondrules in CR chondrites show a different $\Delta^{17}O$-Mg# trend from Acfer 094 (Fig. 2b). Type I chondrules cluster at –2‰ in $\Delta^{17}O$ [22-23] with more Mg-rich chondrules (Mg#≥98) being lower in $\Delta^{17}O$ down to –5‰ [23-24], while $\Delta^{17}O$ values of type II chondrules range from –2‰ to +1‰ [25]. Cryptocrystalline chondrules in CH chondrites show bimodal $\Delta^{17}O$ values of –2‰ and +1.5‰ for FeO-poor and FeO-rich ones, respectively, while those of the porphyritic chondrules scatter from –5‰ to +5‰ [11,26].

Among the carbonaceous chondrite groups described here, the Δ[17]O-Mg# trend of the Wild 2 particles most resembles that of CR chondrules, though they are not identical. This is consistent with the view of a possible link between Wild 2 particles and CR-clan chondrites based on petrology [27], wide variations of the nitrogen isotope ratios [2,28], and the presence of [16]O-rich, Mn-rich forsterites (see above).

Crystalline silicates including Mn-rich forsterites may have been transported from the inner solar nebula to the cometary regions and captured by an accreting comet Wild 2 [3,29]. Given the CR-like Δ[17]O-Mg# trend of the Wild 2 particles (Fig. 2), it is suggested that majority of crystalline silicate particles were derived from the outer regions of the asteroid belt where carbonaceous chondrites formed.

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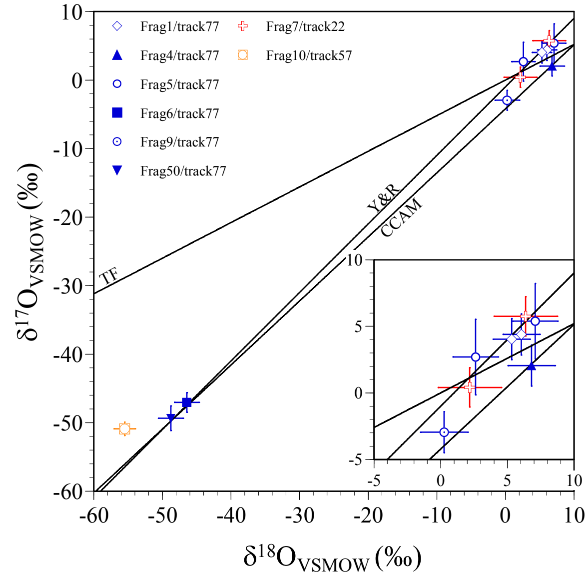

Fig. 1: Oxygen isotope ratios of the eight Wild 2 particles. TF, CCAM [30], and Y&R [31] lines are shown as reference.

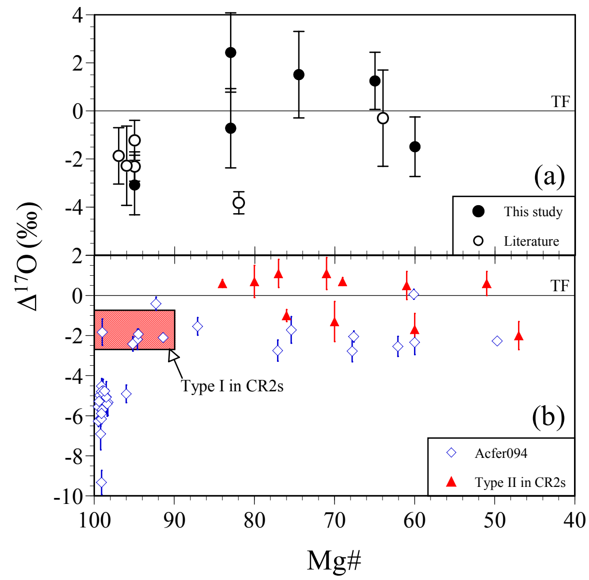

Fig. 2: Comparison of Δ[17]O values with Mg#'s for ferromagnesian Wild 2 particles excluding [16]O-rich particles (a) and Acfer 094 and CR2 chondrite chondrules (b). Literature data of Wild 2 particles are from [3,5-6]. The Δ[17]O values and Mg#'s of carbonaceous chondrite chondrules are from Ushikubo et al. [19] for Acfer 094 and Krot et al. [22] and Connolly and Huss [25] for CR2 chondrites.