

HETEROGENEITY OF BULK OXYGEN ISOTOPIC COMPOSITIONS IN ANHYDROUS INTERPLANETARY DUST PARTICLES.

B. Schulz¹, C. Vollmer¹, L.P. Keller² and P. Hoppe³, ¹Institut für Mineralogie, Universität Münster, Corrensstr. 24, 48149 Münster, Germany (b_schu64@uni-muenster.de), ²XI3, ARES Division, NASA Johnson Space Center, Houston, TX 77058, USA ³Max-Planck-Institut für Chemie, Hahn-Meitner-Weg 1, 55128 Mainz, Germany.

Introduction: Anhydrous interplanetary dust particles are one of the least altered ancient solar system materials. Their bulk chemical compositions match those of CI chondrites within a factor of 2-3, except for carbon which is enriched in both anhydrous and hydrated IDPs by ~4x CI [1]. Hydrous IDPs often show ¹⁶O-poor isotopic compositions, likely due to the interaction with isotopically heavy H₂O [2]. Anhydrous IDPs are interpreted to originate from comets from the outer solar system [3]. Oxygen isotopic data for these materials is scarce, but results point to a wider range of compositions [4]. This heterogeneity might be a result of mixing between a ¹⁶O-rich and a ¹⁶O-poor reservoir formed via self-shielding and photodissociation of CO [5]. Here, we report bulk oxygen isotopic compositions of three anhydrous IDPs in context of their mineralogical composition and discuss possible origins of isotopic heterogeneity.

Experimental: Bulk chemical composition and mineralogy of 70 nm thin ultramicrotomed sections of three anhydrous IDPs (L2099A7, L2099A8, and L2071AB1) were analyzed using a Thermo Scientific Titan Themis G3 60-300 TEM equipped with a four-quadrant energy-dispersive X-ray detector (Super-X G2) at University of Münster. Bulk oxygen isotopic compositions were measured using a NanoSIMS 50 at the Max-Planck-Institut für Chemie in Mainz. A focused Cs⁺ ion beam (~1 pA, ~100 nm) was rastered over a field of view varying from 5 x 5 to 6 x 6 μm², depending on particle size for 15 layers. Negative secondary ions of ¹⁶O, ¹⁷O, ¹⁸O, ¹²C¹⁴N, and ²⁸Si were collected on electron multipliers. The ¹⁶OH contribution to the ¹⁷O peak was 1-2 ‰. As a standard, a matrix region of meteorite CR2 Queen Alexandra Range (QUE) 99177 was used, whose oxygen isotopic composition was measured by [6].

Results and Discussion: Particles A7 and A8 are both fine-grained, consisting mostly of small, 100 nm-sized equilibrated aggregates (EA). Both particles exhibit discontinuous magnetite rims with thicknesses up to 50 nm in A7 and 100 nm in A8 on the outsides. In Particle AB1, the upper part of the particle consists of a few EAs, while the lower part contains lots of small GEMS grains with 100-200 nm diameter clustered together. Magnetite rims are nearly absent, the rare rims reaching maximum 20 nm thickness, indicating that AB1 is of more primitive nature than the other two IDPs [1]. Furthermore, it contains several diffuse GEMS-like areas, identified by an amorphous silicate groundmass with small nano-inclusions of Fe,Ni-metal and Fe-sulfides. All three particles are subsolar for all major element/Si ratios. Mean S/Si of particles A7 and A8 is 0.046 and 0.048, respectively, while it is an order of magnitude higher in AB1 (0.184). This reflects the higher degree of thermal alteration in A7 and A8, resulting in the loss of volatile S and oxidation of Fe-sulfides and FeNi-metal to magnetite as present in particle rims. A8 is rather ¹⁶O-poor with $\delta^{17}\text{O}_{\text{SMOW}} = 7.8 \pm 3.4 \text{ ‰}$ and $\delta^{18}\text{O}_{\text{SMOW}} = 9.5 \pm 3.1 \text{ ‰}$ (1σ), followed by A7 with $\delta^{17}\text{O}_{\text{SMOW}} = -0.8 \pm 4.6 \text{ ‰}$ and $\delta^{18}\text{O}_{\text{SMOW}} = -2.2 \pm 3.4 \text{ ‰}$. In contrast to that, AB1 has the most ¹⁶O-rich bulk composition with $\delta^{17}\text{O}_{\text{SMOW}} = -24.2 \pm 5.4 \text{ ‰}$ and $\delta^{18}\text{O}_{\text{SMOW}} = -25.3 \pm 3.6 \text{ ‰}$. All investigated IDPs plot slightly above the CCAM line as previously reported for other anhydrous IDPs [4], maybe due to a contribution from circumstellar dust from AGB stars enriched in ¹⁷O [7]. The ¹⁶O-rich composition of AB1 is similar to the most ¹⁶O-rich anhydrous IDP U2015D21 measured by [8] which is dominated by GEMS [9] and the GEMS-rich IDP GM4-2 reported by [10]. Nevertheless, it is unlikely that GEMS are the carrier for the ¹⁶O-rich composition of AB1 because most GEMS have O isotopic compositions indistinguishable from terrestrial values, although errors on these analyses are large [11]. The isotopic heterogeneity is best explained by contribution of grains from different regions in the protoplanetary disk, sampling different O isotope reservoirs, created by self-shielding and photodissociation of CO. This process resulted in ¹⁶O-rich CO gas and ¹⁶O-poor H₂O that froze as ice-mantles onto dust grains [12]. Alternatively, the higher degree of heating in A7 and A8 could have influenced isotopic fractionation, because higher $\delta^{17,18}\text{O}$ values are reported from the regions of the atmosphere where small particles are heated and oxidized, as observed for the thermal alteration of cosmic spherules [13].

Acknowledgements: We would like to thank NASA Astromaterials Acquisition & Curation Office for providing IDP samples and DFG for funding this project (VO1816/5-1).

References: [1] Bradley J.P. (1988) *Geochimica et Cosmochimica Acta* 52:889-900. [2] Keller L.P. and Snead C.J. (2021) *LPS LII*, Abstract #2389. [3] Bradley J.P. and Brownlee D.E. (1986) *Science* 231:1542-1544. [4] Starkey N.A. and Franchi I.A. (2013) *Geochimica et Cosmochimica Acta* 105:73-91. [5] Yurimoto H. and Kuramoto K. (2004) *Science* 305:1736-1766. [6] Schrader D. et al. (2014) *Earth and Planetary Science Letters* 407:48-60. [7] Nittler L. and Gaidos E. (2012) *Meteoritics and Planetary Science* 47:2031-2048. [8] Nguyen A.N. et al. (2021) *MAPS LXXXIV*, Abstract #2609. [9] Nguyen A.N. et al. (2015) *LPS XLVI*, Abstract #2868. [10] Aléon J. et al. (2009) *Geochimica et Cosmochimica Acta* 73:4558-4575. [11] Keller L.P. and Messenger S. (2011) *Geochimica et Cosmochimica Acta* 75:5336-5365. [12] Krot A. et al. (2020) *Science Advances* 6. [13] Clayton R.N. et al. (1986) *Earth and Planetary Science Letters* 79:235-240.