

In situ oxygen three-isotope analysis of carbonates with 15 μ m and 3 μ m beam: Preliminary results

Takayuki Ushikubo¹ and Wataru Fujiya²

¹Kochi Institute for Core Sample Research, JAMSTEC

²Faculty of Science, Ibaraki University

Introduction

Carbonates are common secondary minerals in carbonaceous chondrites and they precipitated from fluids during the aqueous alteration in carbonaceous chondrite parent bodies at ca. 4563Ma [1-3]. Occurrence of carbonates with distinct textures (e.g. monocrystalline type 1 calcite vs. porous and polycrystalline type 2 calcite [4]) within the same chondrite and/or existence of chemical zoning in individual crystals [e.g. 5] indicate that carbonates formed at multiple stages of thermal evolution of chondritic parent bodies. Oxygen and carbon isotopic compositions of carbonates very likely record information of physicochemical evolution of aqueous solutions and carbonaceous chondrite parent bodies [e.g. 1]. However, since the presence of H₂O significantly increases the oxygen diffusivity in carbonate [6,7], careful investigations are needed to distinguish primary isotopic signatures recorded in fine-scale structures of carbonate from later isotopic disturbance after carbonate formations. Here, we report results of oxygen isotope test analyses of standard carbonates by SIMS with different primary beam settings. We also measured oxygen isotope ratios of carbonate in Nogoya CM2 chondrite.

Analytical Conditions

Oxygen three-isotope ratios of carbonate (Calcite and Dolomite) were measured with the large-radius multi-collector SIMS (MC-SIMS), CAMECA IMS 1280-HR at Kochi Institute for Core Sample Research, JAMSTEC. Test measurements of the terrestrial standards, UWC-3 calcite [8] and UW-6220 dolomite [9], were performed using two distinct primary beam conditions: one is the normal Cs beam condition (¹³³Cs⁺, total accel. voltage 20 kV, 2.5 nA, and 15 μ m in diameter) and the other is the small beam condition (¹³³Cs⁺, total accel. voltage 20 kV, 30 pA, and 3 μ m in diameter). Three Faraday Cup (FC) detectors were used to detect secondary O⁻ ions for the normal beam condition, and one FC (for ¹⁶O⁻) and two electron multiplier (EM, for ¹⁷O⁻ and ¹⁸O⁻) detectors were used for the small beam condition, respectively. Analytical conditions are basically same as those reported in [10,11]. For the measurements of calcite in Nogoya (CM2), the small beam condition was employed.

Results and Discussion

With the normal Cs beam condition (15 μ m in diameter), the reproducibility (2 SD) of the spot-to-spot analyses was $\pm 0.26\%$ (for $\delta^{18}\text{O}$) and $\pm 0.38\%$ (for $\Delta^{17}\text{O}$) for UWC-3 calcite (N=10), and $\pm 0.49\%$ (for $\delta^{18}\text{O}$) and $\pm 0.52\%$ (for $\Delta^{17}\text{O}$) for UW-6220 dolomite (N=10), respectively. Since the reproducibility of the $\Delta^{17}\text{O}$ value is mainly constrained by the S/N of ¹⁷O⁻ signal, we expect that better reproducibility can be achieved with a higher intensity primary beam. With the small beam condition (3 μ m in diameter), that was $\pm 0.70\%$ (for $\delta^{18}\text{O}$) and $\pm 0.84\%$ (for $\Delta^{17}\text{O}$) for UWC-3 calcite (N=8), and $\pm 1.7\%$ (for $\delta^{18}\text{O}$) and $\pm 1.3\%$ (for $\Delta^{17}\text{O}$) for UW-6220 dolomite (N=10), respectively.

A typical reproducibility (2 SD, N=8 to 10) of the bracketing analyses of UWC-3 during the Nogoya carbonate measurement session was $\pm 1.4\%$ for $\delta^{18}\text{O}$ and $\pm 1.0\%$ for $\Delta^{17}\text{O}$, respectively. Oxygen isotope data of Nogoya calcite show that (1) the type 1 (solid and monocrystalline) and the type 2 (porous and polycrystalline) calcite grains in Nogoya have distinct oxygen isotopic compositions, and (2) their oxygen isotope ratios are distributed along a trend line with the slope of ~ 0.67 (Figure 1). These are consistent with previously reported CM chondritic carbonate data [4]. The MC-SIMS has capability to investigate oxygen three-isotope ratios of carbonate down to a few μ m in size.

References

- [1] Alexander C. M. O'D. et al. 2015. *Meteoritics & Planetary Science* 50: 810. [2] Fujiya W. et al. 2012. *Nature Communications* 3: 627. [3] Fujiya W. et al. 2013. *Earth & Planetary Science Letters* 362: 130. [4] Lindgren P. et al. 2017. *Geochimica et Cosmochimica Acta* 204: 240. [5] Fujiya W. et al. 2015. *Geochimica et Cosmochimica Acta* 161: 101. [6] Farver J. R. 1994. *Earth & Planetary Science Letters* 121: 575. [7] Labotka T. C. et al. 2000. *American Mineralogist* 85: 488. [8] Kozdon R. et al. 2009. *Chemical Geology* 258: 327. [9] Śliwiński M. G. et al. 2016. *Geostandard & Geoanalytical Research* 40: 157. [10] Kita N. T. et al. 2009. *Chemical Geology* 264: 43. [11] Ushikubo T. et al. 2017. *Geochimica et Cosmochimica Acta* 201: 103.

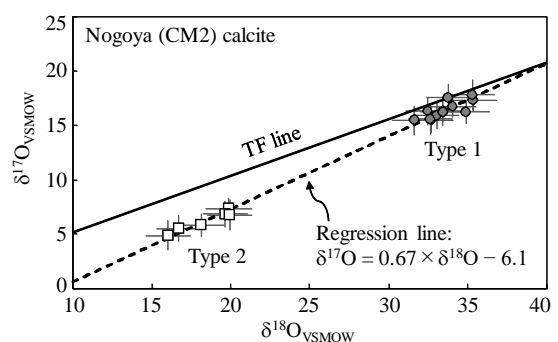


Figure 1. Oxygen three-isotope ratios of type 1 (monocrystalline) and type 2 (polycrystalline) calcite grains in Nogoya CM2 chondrite. Errors are 2 SD.