

MINERALOGY, CHEMISTRY, AND OXYGEN ISOTOPIC COMPOSITIONS OF CHONDRULES FROM THE SAU 290 CH3 CHONDRITE. D. Nakashima^{1,2}, T. Ushikubo¹, N. T. Kita¹, and K. Nagao². ¹Department of Geoscience, University of Wisconsin-Madison, Madison, WI 53706, USA (naka@geology.wisc.edu), ²Laboratory for Earthquake Chemistry, University of Tokyo, Tokyo 113-0033, Japan.

Introduction: Chondrules in CH chondrites are mostly cryptocrystalline (CC) (75%; [1]). Such non-porphyrific chondrules had formed via complete melt, and their chemistry is considered to have been strongly affected by ambient gas relative to porphyritic chondrules. It is expected that the CH chondrite chondrules have recorded environment of the chondrule formation.

Nonporphyritic chondrules in CH chondrites show various textures and chemistries, which are related to formation sequence of the chondrules [2]. Meanwhile, oxygen isotopic ratios of CH chondrules show wide variation ($\delta^{17,18}\text{O} \sim -75$ to $+10\text{‰}$; [3,4]). However, relation among textures, chemistries, and O isotope ratios of the CH chondrules are not clear.

It was reported that Ca-Al-rich inclusions in the Sayh al Uhaymir (SaU) 290 CH3 chondrite are free from secondary alteration products [5]. The SaU 290 chondrules are expected to preserve pristine nature. Here we report results of mineralogical, chemical, and O isotope analyses of the SaU 290 chondrules, and discuss the formation condition of the CH chondrules.

Analytical procedure: Eight chondrules (100–200 μm in diameter) from SaU 290 chondrites [6] were selected for this study. Bulk mineralogy of individual chondrules was investigated by synchrotron radiation X-ray diffraction (SR-XRD) using Gandolfi camera. The chondrules were individually mounted into 5.6mm epoxy disks with San Carlos olivine for O isotope analyses, and were observed with a SEM. The chemical compositions were measured with an EPMA using focused and defocused beams.

O isotopes were analyzed with Wisc-SIMS Cameca IMS-1280 ion microprobe at UW-Madison. We used a newly developed sample holding disk for the small epoxy disks [7]. Two sizes of primary Cs^+ beams ($10 \times 15 \mu\text{m}$ with a current of $\sim 2.5 \text{ nA}$ and $3 \times 4 \mu\text{m}$ with $\sim 28 \text{ pA}$) were applied. Secondary O^- ions were detected with three Faraday cups simultaneously for large beam analyses, while for small beam analyses these were detected with one Faraday cup (for $^{16}\text{O}^-$) and two electron multipliers (for $^{17,18}\text{O}^-$) simultaneously. Other analytical conditions and measurement procedures were similar to those in [8,9]. External reproducibility of large beam analysis of the standard San Carlos olivine was $0.2\text{--}1.8\text{‰}$ for $\delta^{18}\text{O}$, $0.5\text{--}1.6\text{‰}$ for $\delta^{17}\text{O}$, and 0.5--

0.9‰ for $\Delta^{17}\text{O}$ ($=\delta^{17}\text{O}-0.52 \times \delta^{18}\text{O}$) (2SD), while that of small beam analysis was $0.7\text{--}1.8\text{‰}$ for $\delta^{18}\text{O}$, $0.7\text{--}1.6\text{‰}$ for $\delta^{17}\text{O}$, and $0.7\text{--}1.1\text{‰}$ for $\Delta^{17}\text{O}$ (2SD).

Results and discussion: SR-XRD, SEM, and EPMA analyses showed the chondrules are the pyroxene-dominant magnesian fine-grained/CC type (Fig. 1), except for a glassy chondrule Ch03. Bulk compositions of Ch01 and Ch06 are distinct from those of other magnesian CC chondrules in respect of depletion of Mg and enrichment of refractory (Ca, Al, and Ti) and volatile (Mn and Na) elements (Fig. 1c), suggestive of different formation condition.

Ch01 has fan-like radiating pyroxene laths ($\sim 1 \mu\text{m}$; En96; Fig. 1a) with feldspathic phase. High-Ca pyroxene (En77Wo22) occurs around the periphery. The SR-XRD pattern of Ch03 shows no reflection line, indicative of glass. Ch03 is composed only of Al_2O_3 (49.1wt%) and SiO_2 (50.4wt%). Ch06 consists of two distinct pyroxene (En94Wo5 and En98; 2–10 μm ; Fig. 1b) and silica phase (1–3 μm ; probably cristobalite).

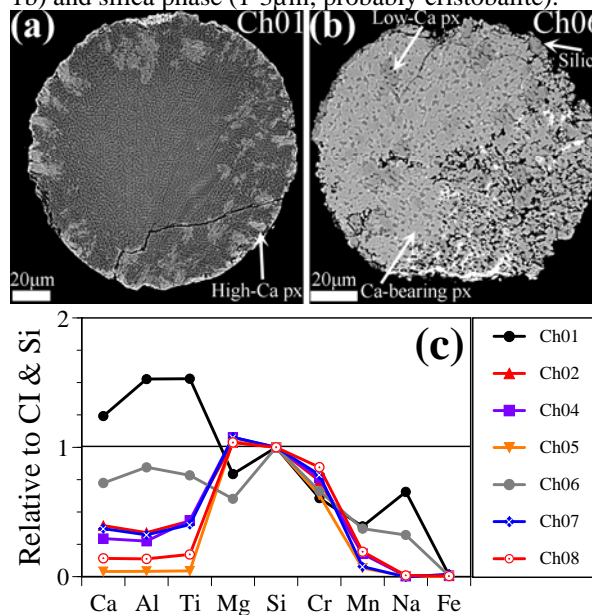


Fig. 1: Back scattered electron images of the SaU 290 chondrules; (a) Ch01 and (b) Ch06. (c) Bulk chemical compositions of the SaU 290 chondrules (Ch03 is not plotted).

O isotope ratios of the individual chondrules analyzed by large beam (three points each) are consistent

within the errors (Fig. 2a), indicating that O isotope compositions of the individual chondrules are homogeneous. O isotope analyses by small beam aimed to observe isotopic heterogeneity in individual pyroxene grains with various compositions, but even in a smaller scale (Fig. 2b) the O isotope ratios are consistent within the errors, except for Ch06. The heterogeneous O isotope ratios in Ch06 along the slope of ~ 0.6 may be due to a contribution of silica which has an instrumental bias of $\sim 7\text{‰}$ ($\delta^{18}\text{O}$) relative to pyroxene [10]. Overall, the SaU 290 chondrules would have formed from silicate melt with individually homogeneous O isotope compositions.

O isotope ratios of the chondrules plot between CCAM and Y&R lines (Fig. 2), and the variation among the chondrules is within the range of other CH chondrite chondrules [4]. Most of the SaU 290 chondrules are depleted in both refractory and volatile elements (Fig. 1c) and have nearly identical isotope ratios: $\Delta^{17}\text{O} = -2.2 \pm 0.6\text{‰}$ with average (2SD; Fig. 2a), which is consistent with those of magnesian CC chondrules in CH/CB and CB chondrites [11]. This supports view that most of the magnesian CC chondrules in CH and CB chondrites formed by a common formation event [11]. Given that the pyroxene (and silica) formed from the melt equilibrated with ambient gas [12], the $\Delta^{17}\text{O}$ value of -2.2‰ may reflect that of the nebular gaseous reservoir at the formation event.

Three chondrules have distinct $\Delta^{17}\text{O}$ values ($\sim 2.2\text{‰}$ for Ch01, $\sim -0.3\text{‰}$ for Ch03, and $\sim -6.4\text{‰}$ for Ch06) from others (Fig. 2a). It was suggested that silica-rich chondrules formed after CC chondrules [2]. The silica-rich Ch06 is expected to be more ^{16}O -depleted than others [13], but Ch06 is ^{16}O -richer than others. Ch01 is richer in refractory elements than others (even exceeds CI abundance; Fig. 1c). This implies the earlier formation than other magnesian CC chondrules, which leads to ^{16}O -enrichment [13]. However, Ch01 is more ^{16}O -depleted than others. Although secondary alteration might be responsible for the ^{16}O -depletion, secondary alteration product such as nepheline or sodalite was not observed in Ch01. As for Ch03, given the distinct $\Delta^{17}\text{O}$ values and non-chondritic compositions, Ch03 is distinct from other SaU 290 chondrules in origin. Thus, the observed isotopic heterogeneity among the chondrules, which are uncorrelated with their mineralogy and chemistry, may reflect variation in O isotopic compositions of the nebular gaseous reservoir temporally or spatially.

References:

- [1] Scott E. R. D. (1988) *EPSL*, 91, 1-18. [2] Hezel D. C. et al. (2003) *MAPS*, 38, 1199-1215. [3] Kobayashi S. et al. (2003) *GJ*, 37, 663-669. [4] Yoshitake M. and Yurimoto H. (2004) *Workshop CPD*, #9049. [5] Zhang A. and Hsu W. (2009) *MAPS*, 44, 787-804. [6] Nakashima D. and Nagao K. (2008) *MAPS*, 43, A112. [7] Nakashima D. et al. (2010) This volume. [8] Kita N. T. et al. (2009) *Chem. Geol.*, 264, 43-57. [9] Nakamura T. et al. (2008) *Science*, 321, 1664-1667. [10] Valley J. W. and Kita N. T. (2009) Mineralogical Association of Canada Short Course 41, Tronto, May 2009: 19-63. [11] Krot A. N. and Nagashima K. (2008) *MAPS*, 43, A81. [12] Libourel G. et al. (2006) *EPSL*, 251, 232-240. [13] Clayton R. N. (1993) *Annu. Rev. Earth Planet. Sci.*, 21, 115-149. [14] Young E. D. and Russell S. S. (1998) *Science*, 282, 1874-1877. [15] Clayton R. N. et al. (1977) *EPSL*, 34, 209-224. [16] Park J. et al. (2005) *Antarctic Meteorites*, 29, 69-70.

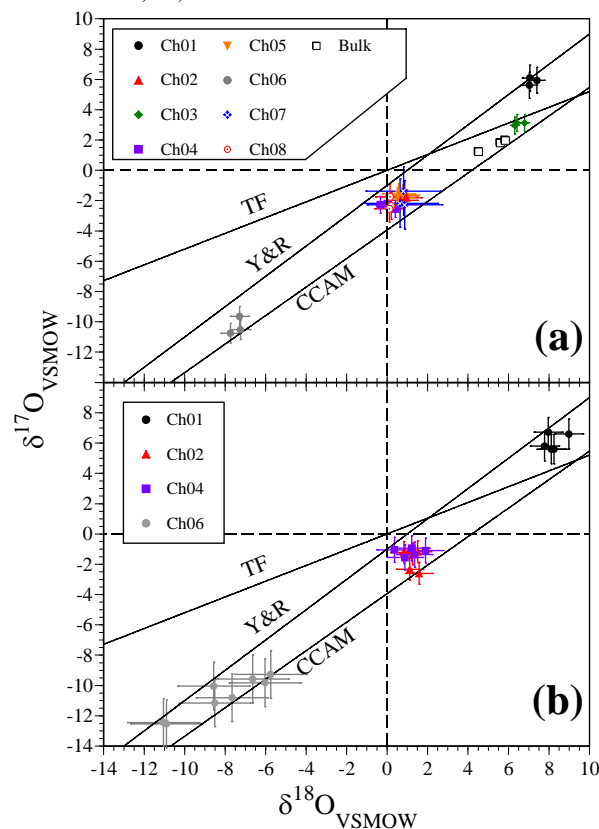


Fig. 2: Oxygen isotopic compositions of the SaU 290 chondrules analyzed by large primary beam (a) and small primary beam (b). TF, Y&R, and CCAM represent the terrestrial fractionation line, the Young & Russell line [14], and the carbonaceous chondrite anhydrous mineral line [15]. Oxygen isotopic ratios of the bulk meteorite are from [16].