

OXYGEN ISOTOPE MICROANALYSIS OF ENVELOPING COMPOUND CHONDRULES IN CV3 AND LL3 CHONDRITES. T. Akaki¹ and T. Nakamura¹. ¹Department of Earth and Planetary Science, Faculty of Science, Kyushu University, Hakozaki, Fukuoka 812-8581, Japan. (Akaki@geo.kyushu-u.ac.jp)

Introduction: The mineralogical and isotopic properties of compound chondrules constrain the physicochemical conditions of chondrule formation events. Compound chondrules were classified into three groups: enveloping, adhering, and consorting types according to the criteria given in [1]. The enveloping type has a core chondrule within a host chondrule, whereas the adhering and consorting types consist of two chondrules fused together.

In this paper, we reported the results of oxygen isotope microanalysis of four enveloping compound chondrules (#29, #30, #23 and #16) in CV3 chondrites: Allende and Axtell, and one enveloping compound LL#7 in the Y790448 LL3.2 chondrite.

Petrography and Isotopipes: Prior to the isotopic analysis, we have measured the bulk chemical compositions of 18 chondrules from 9 enveloping compounds in CV3 and LL3 chondrites, including 5 compounds for which oxygen isotope compositions were analyzed. The result indicates that, for both CV3 and LL3 enveloping compounds, the host chondrules tend to have higher FeO and lower Al₂O₃ and CaO contents than the core chondrules. The results are consistent with the enveloping-type formation model [1], which envisages the enveloping type was formed by a flash melting of a porous Fe-rich dust clump on a preexisting core chondrule. Thus, enveloping types need two times of heating for the formation. Next, the petrography and oxygen isotopic signatures of each enveloping compound are described.

Compounds CV#29 and CV#30; both CV#29 and CV#30 compound chondrules consist of a barred olivine (BO) core enveloped by porphyritic olivine (PO) host. In the CV#30, the discontinuous olivine shell of the BO core is observed along the boundary to the host, whereas in sample CV#29, the olivine shell of the BO core is entirely absent at the border between two chondrules, and the olivine phenocrysts of the PO host are in direct contact with the mesostasis of the BO core chondrule [2]. The partial or total absence of olivine shells in the BO core chondrule indicate that the olivine shells were melted and disappeared when in contact with the host chondrule melt at high temperatures.

The results of the oxygen isotope measurement (Fig. 1) in the CV#30 indicate that the core and the host have similar compositions in a range from -5 to 5‰ in δ¹⁸O_{SMOW} and from -10 to 0‰ in δ¹⁷O_{SMOW}. On the other hand, in the CV#29, the host chondrule have a wider oxygen isotopic variation (δ¹⁸O_{SMOW} ranges from -12 to 3‰), whereas the olivines in the core have a

narrow range of isotopic variation (δ¹⁸O_{SMOW} ranges between -5 and 0‰).

Compounds CV#23; Both the core and the host chondrules are composed of olivine, low-Ca and high-Ca pyroxenes, and plagioclase (Fig. 2a). The olivine shell at the peripheral portion of the core chondrule (marked by arrows in Fig. 2a), which show simultaneous extinction under cross-polarized light, was melted to produce an opening through which a large lath-shape low-Ca pyroxene grows from the host and extends toward the inside of the core chondrule (marked by arrow in Fig. 2b). This implies that the low-Ca pyroxene crystallized before the solidification of the inner portion of the core chondrule. Therefore, the mixing of the chondrule melts between the core and the host occurred during the second heating event. The above discussion is verified by the similarities of the bulk chemical and the oxygen isotope compositions between the two chondrules. Especially, the FeO-enrichment in the host chondrule, which is a common feature among other enveloping compounds, was not observed in CV#23 compound. All oxygen data of the two chondrules lie on or close to the CCAM line in a same range of δ¹⁸O_{SMOW} from -5 to 5‰.

Compound CV#16; the core consists of spinel, low-Ca pyroxene and plagioclase, whereas the host consists of olivine, low-Ca pyroxene and plagioclase. A troilite layer is observed at the boundary in CV#16, while a clear boundary is not recognized where the troilite layer is not present [2]. The blurred boundary implies that the peripheral portion of the core was partially melted together with the host chondrule at the second heating event.

In the core, the subhedral to euhedral spinels occur within coarse pyroxene crystals, and plagioclase fills interstices between the former two phases. The texture of the core chondrule indicates a crystallization sequence in the order of spinel, pyroxene, and then plagioclase. The degree of ¹⁶O enrichment in the core correlates with the textually inferred crystallization sequence, that is, spinel (-15‰), pyroxene (~0‰) and then the plagioclase (~15‰) (Fig. 3). This correlation may result from incomplete O isotopic exchange with ¹⁶O-poor nebular gas under a rate-limiting process such as diffusion in melt and/or surface reaction.

Compound LL#7 in Y790448 LL3.2; LL#7 consists of a BO core enveloped by a PO host chondrule. The olivine shell of the BO core is entirely preserved. The inner BO core and the outer PO host consist mainly of forsteritic olivine in the compositional range Fo₉₉ and Fo₉₆₋₉₉, respectively. SIMS analysis indicated that the

olivines in the PO host have an oxygen isotopic variation ($\delta^{18}\text{O}_{\text{SMOW}}$ ranges between -10 to 0‰) slightly wider than the olivines in the BO core ($\delta^{18}\text{O}_{\text{SMOW}}$ range between -6 to 0‰) (Fig. 3). In addition, the difference of isotopic ratios between the olivine and the mesostasis glass in the host ($\delta^{18}\text{O}$; ~5‰) is larger than that in the core ($\delta^{18}\text{O}$; ~0‰). The range of isotopic compositions overlap with that of the olivine grains in Semarkona LL3.0 chondrules [4] ($\delta^{18}\text{O}_{\text{SMOW}} = -1$ to 7‰, $\delta^{17}\text{O}_{\text{SMOW}} = -3$ to 7‰).

Discussion: The fact that the host chondrule are richer in FeO than those in the core is consistent with the relict chondrule model in [1]. If enveloping compounds formed in a way expected from the relict chondrule model, the core chondrules melted again to varying degrees during the second heating event, as was suggested by the results of experimentally reproduced enveloping compounds via some dust coating and flash melting [5]. We found petrologic evidence showing varying degrees of melting of core chondrules. In the sample LL#7, the olivine shell of the BO core is entirely preserved. On the other hand, in compounds CV#30 and CV#16, only the peripheral portion of the core was melted together with the host, whereas the outer portion of the BO core was entirely melted in the case of CV#29. Further, in compound CV#23, the core chondrule was melted almost totally leaving only an incomplete olivine shell. If a core chondrule and its surrounding Fe-rich dust aggregate were melted altogether at the second heating event, a larger FeO-rich single chondrule would have formed. The existence of enveloping compound chondrules formed by the relict chondrule model suggests that chondrules experienced a heating event twice or more, and chondrules and Fe-rich dust existed together in a certain region of the nebula at the time of chondrule formation.

The constant oxygen isotope ratios in the BO cores of CV#29 and LL#7 indicate the homogenization of oxygen isotopes in a totally melting chondrule with gaseous reservoirs, while partial exchange of oxygen isotopes with gaseous reservoir resulted in the heterogeneous oxygen composition within the PO host. If the total exchange of oxygen isotopes have occurred in the BO core melt at the first heating event, the difference of oxygen isotope ratios between CV#29 and LL#7 BO cores indicates the different isotope compositions of gaseous reservoirs between regions of the nebula. Furthermore, the similarity of the oxygen isotope compositions between the host and the conjugated core indicates that the oxygen isotope composition of the nebular gases reservoirs have not changed during the multiple heating events that formed CV or LL compounds.

References: [1] Wasson J. T. et al. (1995) *G.C.A.* **59**, 1847–1869. [2] Akaki T. and Nakamura T. (2004) *G.C.A.* in press. [3] Clayton R. N. (1993) *Annu. Rev. Earth Planet. Sci.* **21**, 115–149. [4] Sears D. W. G. et al. (1998) *Meteorit. Planet. Sci.* **33**, 1029–1032. [5] Connolly H. C., Jr. and Hewins R. H. (1996) *Lunar Planet. Sci.*, **27**, 247.

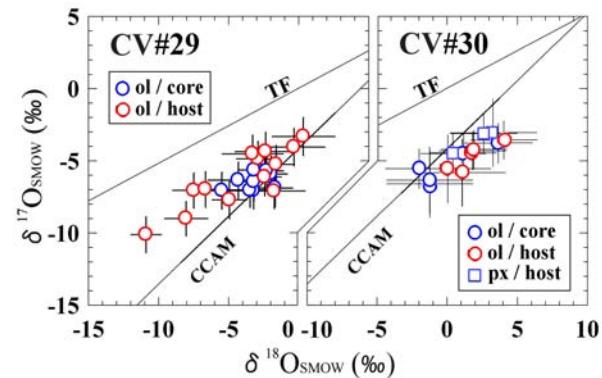


Fig. 1. Oxygen isotopic compositions of the minerals in CV#29 and CV#30 compounds. TF=Terrestrial Fractionation, CCAM=Carbonaceous Chondrite Anhydros Minerals. ol=olivine, px=pyroxene.

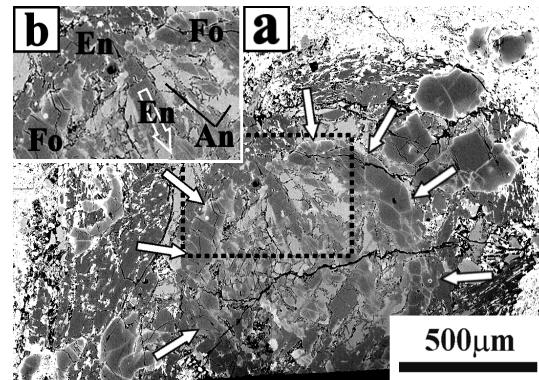


Fig. 2 . (a) The BSE image of compound CV#23. (b) The enlarged image of the boundary. Fo=forstelite, En=enstatite, An=anorthite.

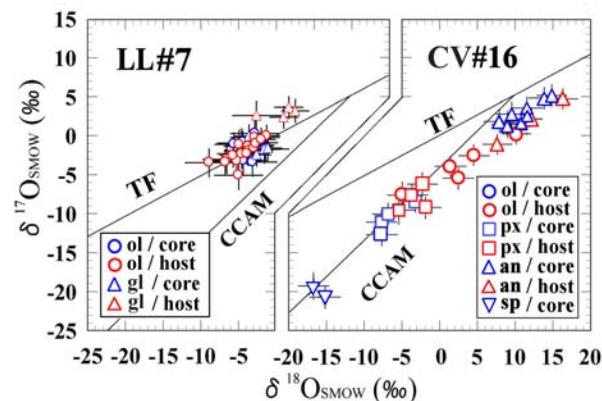


Fig. 3. Oxygen isotopic compositions of the minerals in LL#7 and CV#16 compounds. ol=olivine, px=pyroxene, an=anorthite, sp=spinel, gl=mesostasis glass.