

局所サンプリングによるCRコンドライト中のメタル相における強親鉄性元素及びオスミウム同位体分析

Determination of highly siderophile elements and osmium isotope compositions in metal phases from CR chondrites using micro sampling technique

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Metal plays a key role in physicochemical processes that fractionate siderophile elements from lithophile elements in the early solar system, generating variable chemical reservoirs before the onset of planetesimal formation. Highly siderophile elements (HSEs: Re, Os, Ir, Ru, Pt and Pd) have great affinity for Fe-Ni metals relative to silicates. HSEs are refractory and exist as gas only at high temperatures. Therefore, geochemical investigation on HSEs in metal phases for a variety of meteorites can provide an important clue for understanding high temperature processes in the solar nebula. In particular, the ¹⁸⁷Re-¹⁸⁷Os isotope system gives chronological information regarding the fractionation of HSEs.

CR chondrites contain 40–60 vol. % of chondrules with 5–8 vol. % of metal grains and have unique characteristics for the coexistence of metal phases with chondrules [1, 2]. Therefore, CR chondrites are suitable for understanding the genetic linkage between metals and chondrules. Metal grains are found in three different locations of CR chondrites; chondrule interior (“interior grain”), chondrule surficial shells (“margin grain”), and the matrix (“isolated grain”). Previous studies on CR metals [2, 3] suggested that CR metals could have formed via melting and recondensation of surrounding vapor, although the details for the origin of CR metals remains unclear.

In this study, we tried to establish a formation model for the series of three types of CR metals based on their HSE abundances and Os isotope compositions. We prepared thick sections of three CR chondrites: NWA 801, NWA 7184, and Dhofar 1432. The petrography and the mineral compositions of these sections were examined with SEM-EDX (Hitachi 3400; Bruker Xflash 5010). We analyzed the abundances of HSEs, major (Fe and Ni), and minor (P, S, Cr, and Co) elements for multi-spots of these grains using fs-LA-ICP-MS (IFRIT, Cyber Laser) and EPMA (JEOL-JXA-8530F), respectively. In addition, we determined Os isotope compositions for two isolated grains in NWA 801. The details for Os isotope analysis using a micro milling system and N-TIMS (TRITON plus, Thermo Fisher Scientific) are described in [4].

The Pd/Ir ratios in all types of CR metal grains decreased rapidly with the increase of Ir concentration. Equilibrium condensation of metals from a gaseous reservoir does not account for the large variation of Pd/Ir. From the HSE abundances in metal grains obtained, we calculated the partition coefficients (*D*) of HSEs between solid and liquid metals. We found that the order of *D* values determined for individual HSEs were consistent with those calculated from the experimental partitioning data [5]. Next, we estimated the initial composition of metal phases that fits the observed data points using the fractional crystallization model. The Ir-normalized initial HSE abundances are all chondritic excluding the Pd/Ir ratio. We speculate that Pd could have been lost during chondrule formation process before metal crystallization, because Pd is relatively volatile among the HSEs. From these evidences, we conclude that CR metals have most likely formed via fractional crystallization.

We found that two isolated metals analyzed have $^{187}\text{Os}/^{188}\text{Os}$ ratios (0.1258, 0.1261) close to that of bulk CI (0.1263–0.1265) and CR (0.1253–0.1271) chondrites [6]. Such consistent Os isotope ratios suggest that isolated grains in CR chondrites have formed from a CI-like precursor with preserving the original CI-like $^{187}\text{Os}/^{188}\text{Os}$ ratio without substantial Re-Os fractionation. This scenario is supported by the chondritic HSE (excluding Pd) initial abundances in CR metals estimated by the fractional crystallization model.

References: [1] Lee et al. (1992) GCA, 56, 2521–2533. [2] Jacquet et al. (2013) MAPS, 48, 1981–1999. [3] Connolly et al. (2001) GCA, 65, 4567–4588. [4] Nakanishi et al. (2013) LPSC, abstract #2407. [5] Chabot and Jones (2003) MAPS, 38, 1425–1436. [6] Walker et al. (2002) GCA, 66, 4187–4201.

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