

Determination of in-situ Os isotope compositions in metal phases from CB chondrites using a micro sampling technique

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Metal has played a major role in the early Solar System for fractionating siderophile elements from lithophile elements, generating different chemical reservoirs in the early Solar System. In particular, metal in chondrites has a historic record of thermal and chemical processes in the solar nebula. To examine metal phases, highly siderophile elements (HSEs: Re, Os, Ir, Ru, Pt and Pd) are powerful tracers because HSEs have a great affinity to Fe-Ni metal relative to silicate phases. The origin of metals in chondrites has been extensively studied based on HSE data obtained by LA-ICPMS [e.g. 1-2]. Of all chondrites, CB and CH are metal rich (60-70 vol. %) and thus are interesting target to investigate. The CB chondrites are subdivided into CB_a and CB_b depending on the metal abundances, chondrule sizes and chemical compositions. The origin of CB metals is still debated. One argued that CB_a metals may be the product of an impact plume at planetary collision or other non-nebular event [1], while those in CB_b are thought to be a condensation product in the solar nebula [2]. However, Rubin et al. [3] raised a possibility that CB_b metals formed by condensation in a gas of non-nebular origin, such as an impact plume.

Here we present Os isotopic compositions in metal phases from three CB chondrites with high spatial resolution. In-situ Os isotope analysis by LA-ICP-MS has been hindered because of ¹⁸⁷Re interference. In this study, we collected metal samples using a micro milling system equipped with a diamond drill bit (Geomill 326, Izumo-web) from three CB chondrites, Bencubbin (CB_a), Gujba (CB_a), and Isheyevu (CB_b). A sliced meteorite specimen was drilled with a single drop of Milli-Q water. The drilled metal powder was recovered in a glass vial together with water. To obtain sufficient amount of Os for isotopic analysis, one or two conic pit(s) with a radius of 500 μm and depth of 550 μm was dedicated for a single measurement. The metal powder was dissolved by the mixture of HCl and HNO₃ in a sealed Carius tube, and Os was purified by solvent extraction and micro distillation. Osmium isotopic composition was measured by N-TIMS. The major element compositions and HSE abundances in metals adjacent to the drill pit were measured by EPMA and fs-LA-ICP-MS, respectively.

All the ¹⁸⁷Os/¹⁸⁸Os ratios of CB metals obtained in this study have limited variation (0.1251-0.1273) which fall within the range of bulk carbonaceous chondrites. Interestingly, the majority of CB metals have ¹⁸⁷Os/¹⁸⁸Os ratios close to the bulk CI chondrite (0.1264-0.1265), while the rests have lower values. Furthermore, these data generally plot on the 4.56-Ga Re-Os reference isochron of IIIAB iron meteorites. Therefore, the ¹⁸⁷Os/¹⁸⁸Os variations in CB metals reflects the variation of Re/Os in individual grains at the time of their formation at 4.56 Ga. Osmium isotopic deviation from the CI value would suggest Re-Os fractionation from a putative bulk nebula composition, either in a hot nebula or impact plume. Early removal of a high-temperature condensate may have generated a reservoir with Re/Os less than CI, assuming that Re has been preferentially incorporated into high temperature condensates relative to Os. Our data also suggest limited variation of the other HSE relative abundances such as Os/Ir. However, Pd/Fe and Ni/Fe ratios in CB_a and CB_b metals are all variable with a positive correlation, which cannot be explained by nebular condensation but condensation in extremely high gas pressure (10⁷ x solar nebula). This reconciles with the formation of CB metals in impact plume of planetary collision, while fractionation of HSEs with relatively high 50% condensation temperatures (e.g., Re, Os, Ir) was restricted during metal formation.

References: [1] Campbell, A. et al. (2002) GCA 66, 647 [2] Campbell, A., Humayun, M. (2004) GCA 68, 3409 [3] Rubin A. et al. (2003) GCA 67, 3283

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