^{53}Mn–^{53}Cr systematics of chondrules in CO carbonaceous chondrites

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Chondrules, millimeter-sized spheres with igneous textures in chondrites, are among the first solids to form in our Solar System [1]. Understanding the origin of their formation and their ages is therefore crucial for understanding the early evolution of planets and the Solar Solar in general. The potential age gap between chondrules and calcium- and aluminium-rich inclusions (CAI) is highly debated [1-2]. However, there are some limitations in U-Pb and ^{26}Al-^{26}Mg system for dating chondrules, such as low elemental content of U and Pb, U isotope variation and possible heterogeneous initial ^{26}Al in the protoplanetary disk [3-4]. Therefore, the ^{53}Mn-^{53}Cr chronometry (half-life of 3.7 Myr) may be an effective way to date the small-sized chondrules in CO3 chondrites which experienced the least metamorphism and aqueous alteration but lack of research. Besides, ε^{54}Cr systematics may be a robust tool to trace the origin of chondrules [5].

Cr isotope compositions of nine individual chondrules extracted from Ornans (CO3.4) were analyzed by Triton Plus TIMS, and the related method was decribed in [6]. A well defined external ^{53}Mn-^{53}Cr isochron has been established, showing the initial ^{53}Mn/^{55}Mn of $(7.2 \pm 1.6) \times 10^{-6}$, which can be translated to an absolute age of 4568.1 ± 1.3 Ma or 4567.7 ± 1.3 Ma anchored to LEW86010 and U-corrected D'Orbigny. Therefore, our results support that the CO chondrules are as old as CAIs. In addition, the results demonstrate a large variability of ε^{54}Cr value, ranging from +0.20 to +1.22, and correlate with their ε^{53}Cr value. This may suggest a mixing of materials featured by low (deficit or terrestrial) ε^{54}Cr from relatively inner Solar System and matrix-like precursors characterized by excess of ε^{54}Cr in the accretion region of CO chondrites. According to transportation of material from the inner to outer Solar System and simultaneous formation of CAIs and CO chondrules, X-wind among chondrule formation models is supported for CO chondrules [7].

[1] Connelly et al. 2012, Science. [2] Villeneuve et al. 2009, Science. [3] Larsen et al. 2011, ApJ. [4] Brennecka et al. 2010, Science. [5] Olsen et al. 2016, GCA. [6] Qin et al. 2010, GCA. [7] Shu et al. 1997, Science.