THE DISTRIBUTION OF Hf AND W IN INCLUSIONS FROM METEORITES AND CHRONOLOGY OF THE EARLY SOLAR SYSTEM

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Introduction

The birth of the solar system is marked by a rapid series of events that occurred within the first100 million years (m.y.) from the collapse of a molecular cloud core. Precise dating of events that occurred 4.56 billion years ago is challenging, and is best accomplished by radiometric clocks based on extinct chronometers, i.e. radionuclides that entirely decayed during the first 100 million years of solar system history. One of these chronometers is based on the beta decay of ^{182}Hf (produced in supernovae) to ^{182}W (stable), one of the five isotopes of tungsten, with a half-life of 9 m.y. (Kleine et al., 2005). Application of the ^{182}Hf-^{182}W chronometer requires experimental determination of the initial ratio of ^{182}W/^{184}W in the solar system. The first objects to form as solids in the solar system are the calcium-aluminum-rich inclusions (CAIs) found in the carbonaceous chondrite meteorites. Kleine et al. (2005) reported the first ^{182}Hf-^{182}W ages on the CAIs and obtained an initial ^{182}W/^{184}W identical to that obtained from iron meteorites, implying the formation of the iron meteorites contemporaneously with the condensation of the first solids. This result is difficult to understand since individual chondrites accumulated over periods of several m.y., requiring that bodies large enough to form iron cores must have accumulated over longer periods of time. The meteorite from which the CAIs were obtained (Allende) had experienced a protracted history of post-accumulation disturbances which may have affected the ^{182}Hf-^{182}W ages in these CAIs. We explored this by analyzing the distribution of Hf, W and other elements in the individual minerals constituting CAIs using laser ablation ICP-MS at the NHMFL.

Experimental

Analyses of the distribution of Hf, W, and other elements were performed at the Plasma Analytical Facility at the NHMFL, using a New Wave UP213 UV laser ablation system coupled to a magnetic-sector ICP-MS (Thermo Finnigan Element1). Measurements were performed in line scan mode with 12 or 25 µm beam diameters, with the stage moved at 4-5 µm/s, 10 Hz laser repetition rate and 50% power output. The peaks ^{7}Li, ^{25}Mg, ^{27}Al, ^{29}Si, ^{34}S, ^{43}Ca, ^{49}Ti, ^{53}Cr, ^{57}Fe, ^{60}Ni, ^{180}Hf, ^{181}Ta, ^{182}W, ^{183}W, ^{193}Ir, ^{195}Pt and ^{197}Au were acquired in low resolution (R=300) at 50 ms/peak (Humayun et al., 2006).

Results, Discussion & Conclusions

CAIs are composed of the minerals melilite (Ca-Al silicate), fassaite (Ca-Mg-Al-Ti silicate), spinel ($MgAl_2O_4$) and Fe-Ni metal. The distribution of the elements in CAIs was studied in two chondrites, Allende which had experienced post-accumulational heating, and Efremovka where these effects are relatively minor. The Efremovka CAIs had fairly simple elemental distribution patterns. All the W occurs in Fe-Ni metal grains (up to 1000 ppm), all the Hf occurs in fassaite (12-15 ppm), while melilite and spinel were found to contain negligible quantities (<0.010 ppm). In Allende, the Hf is hosted exclusively in fassaite, as well, but the W-host metal is absent. All Allende Fe-Ni metal has been altered into secondary oxides, sulfides, etc. W-rich veins were found in fassaite in Allende (Humayun et al., 2006). Such mobility is clear evidence for the post-formational disturbance of the ^{182}Hf-^{182}W chronometer in Allende. We find that the ambiguity in the results of Kleine et al. (2005) on the ^{182}Hf-^{182}W chronometry of the early history of the solar system could be resolved by new measurements on CAIs from the Efremovka meteorite.

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References

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