LETTER

Titanium isotopic anomalies in hibonites from the Murchison carbonaceous chondrite

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Abstract—The isotopic compositions of titanium in eight grains of hibonite (CaAl$_2$O$_4$) from the carbonaceous chondrite Murchison have been determined by high precision secondary ion mass spectrometry using an ion microprobe. The titanium in the hibonites varies greatly in $^{50}$Ti, from about $-42$ to $+8$ permil (relative to terrestrial) with smaller (up to 4 permil), but clearly resolvable, effects in $^{46}$Ti and $^{48}$Ti. These results complement ion probe measurements by FAHEY et al. (1985) of a 100 permil excess of $^{50}$Ti in a hibonite grain from the carbonaceous chondrite Murray, and confirm the presence of widespread negative anomalies suggested by the results of HUTCHEON et al. (1983) on hibonites from Murchison. The magnitude of these variations seems explicable only in terms of nucleogenic processes which produced extremely variable titanium isotopic abundances in the hibonite source materials. The hibonites evidently did not participate to the same extent as most material in the mixing and homogenisation processes that accompanied the formation and later evolution of the solar system. Thus, significant source materials of the hibonites may be the supernova condensates of CLAYTON (1978) and may support the concept of "chemical memory" (CLAYTON, 1978; NIEMEYER and LUGMAIR, 1984).

The isotopic composition of titanium in refractory inclusions from meteorites is an important indicator of nucleosynthetic processes. Titanium is on the lower mass side of the iron abundance peak and therefore its composition can reflect variations in the quasi-equilibrium conditions in stellar interiors giving rise to that peak, provided nuclear processing during ingestion into the interstellar medium is minimal (WOOLSEY and WEAVER, 1982). Titanium is important also in having one of the most refractory oxides and is concentrated in refractory inclusions by either condensation or evaporation processes (GROSSMAN, 1972).

A large number of titanium isotopic analyses have been carried out on individual calcium aluminium-rich inclusions (CAI) from Allende and other carbonaceous chondrites by thermal ionisation mass spectrometry. The great majority of these show a 1 permil enhancement of $^{50}$Ti relative to terrestrial ratios (NIEDERER et al., 1980, 1981, 1985; NIEMEYER and LUGMAIR, 1981, 1984; HEYDEGGER et al., 1982). Analyses of the so-called FUN (Fractionation and Unknown Nuclear) inclusions show more diversity, but even here the anomalies are limited to a range of $^{50}$Ti from $-5$ to $+4$ permil (NIEDERER et al., 1981, 1985). Larger anomalies, up to 100 permil, have been discovered using ion microprobes on a small number of hibonite grains from C2M chondrites.

HUTCHEON et al. (1983) first analysed four hibonite inclusions from Murchison using an ion microprobe set at low mass resolution. Two of the hibonites appeared to have a normal titanium isotopic composition but the other two were characterised by large $^{50}$Ti deficits of $-8 \pm 2$ permil (DJ-6), and $-16 \pm 3$ permil (DJ-5). The precision of the data was not sufficient to resolve anomalies in the other isotopic ratios. FAHEY et al. (1985) have recently reported the titanium isotopic composition of three hibonites at high mass resolution to separate all significant isobaric interferences, including $^{46}$Ca, from $^{48}$Ti. Two Murchison hibonites were characterised by excesses of $\sim +8$ permil in contrast to the deficits recorded by HUTCHEON et al. (1983). A hibonite inclusion from Murray has a remarkable signature in having a 100 permil excess in $^{50}$Ti, with effects at the other two normalised ratios clearly resolved.

In this letter we document the presence of widespread titanium isotopic heterogeneities in Murchison hibonites, and independently confirm the large deficits in $^{50}$Ti indicated by the first ion microprobe measurements of titanium in Murchison hibonites by HUTCHEON et al. (1983).

The great virtue of ion microprobe analysis is that isotopic compositions can be determined in situ on a few nanograms of sample. In this study titanium iso-