Correlated morphological, chemical, and isotopic characteristics of hibonites from the Murchison carbonaceous chondrite

TREVOR R. IRELAND

Research School of Earth Sciences, The Australian National University, Canberra, ACT 2601, Australia and Physics Department and McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130, U.S.A.

(Received December 18, 1987; accepted in revised form August 11, 1988)

Abstract—Twenty-four hibonite-dominated refractory grains from the Murchison carbonaceous chondrite have been identified from polished grain-mounts of density separates, and have been morphologically and chemically divided into three groups: (1) 14 colourless PLATy Crystal fragments (PLACs) with less than 2.7% TiO₂; (2) 3 pleochroic Blue Aggregates (BAGs) which are composed of crystal plates and fragments and have TiO₂ concentrations between 5.1% and 6.5%; (3) Six Spinell-Hibonite spherules and crystal aggregates (SHIBs), often with spinel, Fe-silicate, and clinopyroxene rims. The maximum TiO₂ concentrations of hibonite in the SHIBs ranges from 3.5 to 7.6%, but the TiO₂ concentration in one grain was heterogeneous and ranged from 0.5% to 5.0%. Hibonite in all types is stoichiometric with Ti and Mg predominantly in a coupled substitution of Mg²⁺ and Ti⁴⁺ for 2Al³⁺. One grain with a rounded hibonite core does not clearly fit into the three designated groups.

The hibonites have been analysed by ion microprobe mass spectrometry for their Mg and Ti isotopic compositions. Twelve of the PLACs have (²⁶Al/²⁶Mg) ratios less than 1 x 10⁻⁶, but the other two PLACs have (²⁶Al/²⁶Mg) of 5.5 x 10⁻⁶ and 7.7 x 10⁻⁶. The excess ²⁶Mg may reflect initial Mg isotopic heterogeneities in the source region of the PLACs, or be the result of in situ ²⁶Al decay, in which case the distribution of ²⁶Al was heterogeneous. Three BAGs show substantial positive mass-fractionation of Mg. One grain has excess ²⁶Mg while the other two have ²⁶Mg depletions. The ²⁶Mg depletions indicate the presence of Mg isotopic anomalies in the BAGs, but the excess ²⁶Mg in one grain could be due to in situ ²⁶Al decay. The six SHIBs have excess ²⁶Mg that is correlated with ²⁶Al/²⁶Mg. The Mg isotopic systematics of the SHIBs are consistent with the in situ decay of ²⁶Al with (²⁶Al/²⁶Mg) of ca. 5 x 10⁻⁷. The unclassified hibonite has a clearly-resolved deficit in ²⁶Mg. Titanium isotopic anomalies are common in the hibonites measured here. The largest anomalies are in ⁴⁰Ti with variations in ²⁶Ti/²⁴Ti ranging from -50 to +16% relative to terrestrial.

Smaller anomalies are present in ⁴²Ti and ⁴⁰Ti. The Ti isotopic compositions are not directly correlated with morphological type, but the PLACs show the largest variations in isotopic composition, whereas the SHIBs are generally close to terrestrial.

The presence of hibonite populations with distinct morphological, chemical and Mg isotopic systematics suggests that there were several hibonite formation episodes within the early solar system. The hibonites probably formed by the melting of refractory dust aggregates during local transient thermal events.

1. INTRODUCTION

Meteoritic hibonites [Ca(Al,Mg,Ti)₂O₃] contain the most anomalous refractory-element isotopic signatures yet measured. Titanium isotopic analyses have shown large ⁵⁷Ti anomalies with variations in ⁵⁷Ti/⁴⁰Ti from -7% to +10% relative to terrestrial Ti (Hitchchen et al., 1983; Fahey et al., 1985a, 1987a; Ireland et al., 1985; Hinton et al., 1987). Calcium isotopic measurements have shown anomalies in ⁴⁰Ca which are large and of the same sign as the ⁵⁷Ti anomalies in the same grains (Zinner et al., 1986). Magnesium isotopic compositions have shown excess ²⁶Mg up to 400% (Ireland and Compston, 1987), however hibonites commonly show little or no excess ²⁶Mg (Fahey et al., 1987a, and references therein). The oxygen isotopic compositions of seven hibonites, with both positive and negative ⁶⁷O anomalies, were all found to be enriched in ¹⁸O by 4 to 7% relative to the terrestrial standard SMOW (Fahey et al., 1987b).

Trace element compositions of hibonites have also been measured in an attempt to correlate chemical and isotopic characteristics of these grains (Fahey et al., 1985b, 1987a; Hinton et al., 1985, 1987). These authors found that the largest Ti isotopic anomalies are present in hibonite with Group III rare earth element patterns, whereas no hibonites with Group II patterns had Ti isotopic anomalies. Fahey et al. (1987a) also found that, except for one inclusion, the grains with Ti isotopic anomalies did not exhibit ²⁶Mg excesses. Hitchchen et al. (1986) noted that refractory inclusions containing hibonite as the only refractory phase rarely contain excess ²⁶Mg, whereas refractory inclusions containing hibonite associated with spinel and/or melilite had (²⁶Al/²⁶Mg) of approximately 5 x 10⁻⁷. Previous work has therefore suggested that there might be distinct populations of hibonite grains present, but the relatively small population of samples analysed has not allowed a clear definition of any correlated effects.

This paper presents morphological descriptions, chemical analyses, as well as Mg and Ti isotopic compositions, of 24 hibonite grains from the Murchison carbonaceous chondrite. Titanium isotopic compositions of eight of these hibonites were presented in Ireland et al. (1985), and preliminary results of the remaining hibonites were presented in Ireland (1987a). Mg isotopic compositions were presented in Ireland et al. (1986a,b) and Ireland (1987a), but some of these Mg isotopic analyses were subject to analytical error (Ireland, 1987b). Rare earth element and trace element abundances have also been determined and will be presented elsewhere (Ireland et al., 1988).