Kumdykolite, a high-temperature feldspar from an enstatite chondrite

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ABSTRACT

We report the first occurrence of kumdykolite in a meteorite (Sahara 97072, EH3). This orthorhombic form of albite occurs in the core of a concentrically zoned metal-sulfide nodule. In contrast to the terrestrial kumdykolite, the meteoritic sample has a domain structure that is consistent with either orthorhombic (Pmnn) or monoclinic (P21) space groups. The two symmetries are indicated by the presence or lack, respectively, of h+k = 2n + 1 reflections in [001] selected-area electron diffraction patterns, effects that likely result from different Si-Al ordering. Pmnn kumdykolite has only one tetrahedral site for Si and Al, whereas P21, kumdykolite would have three tetrahedral sites for Si and one for Al. We propose that kumdykolite formed above 1300 K and cooled rapidly enough to preserve its unique structure. Apparently, the cooling rate varied on the scale of nanometers allowing the local development of Si-Al ordering.

Keywords: Kumdykolite, albite polymorph, enstatite chondrite, domain structure, Si-Al ordering

INTRODUCTION

Albite is an important Na-bearing mineral in unequilibrated, metal-rich enstatite (EH3) chondrites (Schneider et al. 2002; Lehner et al. 2013a), although it is rare in carbonaceous and ordinary chondrites. It is intimately intergrown with sulfides and silica produced through silicate sulfidation in EH3 chondrites (Lehner et al. 2013a, 2013b). Therefore, albite may carry important information about the sulfidation environment.

The albite structure has the potential to record thermal history (e.g., Smith 1974). At high temperature, it crystallizes with monoclinic symmetry. Below 1273 K, Si-Al ordering occurs (e.g., Salje 1985; Salje et al. 1989), which results in the triclinic high-albite structure. Upon cooling to below 973 K, the ordering leads to unit-cell distortion and formation of low albite (also triclinic). The known high-pressure (>10 GPa) albite polymorph is lingunite (Liu 1978; Liu and El Goresy 2007), with hollandite-type structure. Recently an albite polymorph with orthorhombic symmetry was described from eclogite in the ultrahigh-pressure Kumdy Kol, Kokchetav massif. The polymorph was named kumdykolite and proposed to be metastable, formed by rapid cooling from high temperature (Hwang et al. 2009).

We report the first occurrence of kumdykolite in a meteorite (SAH 97072 EH3). In contrast to the terrestrial example, this kumdykolite has a domain structure and occurs in two forms with different Si-Al ordering. The goals of this paper are to describe its occurrence in an EH3 chondrite, discuss its crystal structure, Si-Al ordering, and its possible formation condition.

EXPERIMENTAL METHOD

Chemical analysis and backscattered electron (BSE) imaging of a concentrically zoned metal-sulfide nodule were performed using a thin section of SAH 97072 with an FEI NOVA scanning electron microscope (SEM). The Si- and Al-rich core of the nodule was extracted and thinned to electron transparency using a focused ion beam (FIB). Transmission electron microscope (TEM) data, bright-field TEM (BFTEM) images, and selected-area electron diffraction (SAED) patterns were acquired with JEOL2000FX and JEOL JEM 4000EX TEMs. The compositions of the grains were measured with an energy-dispersive X-ray spectrometer attached to a JEOL 2010F TEM. We used the Cliff-Lorimer thin-film approximation and ZAF correction to quantify the analyses for Na-loss by using an albite standard under identical conditions.

RESULTS

The nodule consists of a kamacite-troilite mantle and a core containing oldhamite, niningerite, Zn-daubreelite, and S-rich porous silica (Figs. 1a–1c). The porous silica contains grains of NaAlSi2O6 (Table 1) that have SAED patterns consistent with kumdykolite (Figs. 2 and 3).

Kumdykolite was reported in space group Pmnn (Hwang et al. 2009), a symmetry that requires systematic absences for reflections with h+k = 2n + 1 in SAED patterns along [001]. Patterns from some areas of the meteoritic kumdykolite are