

3D microstructure of a cosmic symplectite in primitive carbonaceous chondrite Acfer 094

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Introduction

Oxygen isotopic compositions can be used to identify the origins of planetary materials. Components of carbonaceous chondrites show wide range of oxygen isotopic compositions ($\delta^{17,18}\text{O}$: $\sim -50-0$ ‰) that keep nearly constant $\delta^{17}\text{O}/\delta^{18}\text{O}$ ratio of ~ 1 e.g.,^[1]. The isotopic variation is thought to be resulted from both mass-dependent isotope fractionation and mixing of two distinct reservoirs of ^{16}O -rich and $^{17,18}\text{O}$ -rich in the solar nebula. The composition of the ^{16}O -rich reservoir has been estimated from the isotopic compositions of CAIs and AOs which were originated from the reservoir e.g.,^[2]. Recently, Fe-rich material originated from the $^{17,18}\text{O}$ -rich reservoir, called cosmic symplectite (COS), has been reported from the primitive carbonaceous chondrite Acfer 094^[3]. COS have the heaviest oxygen isotopic composition ($\delta^{17,18}\text{O}$: ~ 180 ‰) among solar materials and consist of nanometer-scaled symplectitically intergrowth of magnetite and Fe-Ni sulfides^[3,4]. They are thought to have formed by oxidation of Fe-Ni metal and sulfides by $^{17,18}\text{O}$ -rich water or water vapor in the early Solar System. However, petrological and mineralogical information of COS still remain limited. In this study, we performed synchrotron radiation-based X-ray computed tomography (SR-XCT) and NanoSIMS analysis to investigate the origin of COS.

Results and discussion

First, we observed a polished Acfer 094 section (~ 2.2 mm²) by FE-SEM and found five COS grains. The COS grains (~ 10 μm) show rope-like structure like as COS reported by Abe et al. (2017)^[5]. One of the five COS grains was extracted as a block ($\sim 25 \times 25 \times 30$ μm) using FIB and analyzed by high spatial resolution (~ 100 nm) SR-XCT at SPring-8 BL47XU. The 3D image shows that the COS grain has irregular shape with many topographic depressions on the surface and contains small (< 1 μm) inclusions. The inclusions are not connected to the outside of the COS by clack, ensuring that they were trapped when the host COS formed. We made a cross section surface of the inclusions using FIB and analyzed it by FE-SEM. The inclusions have Na, S, O rich compositions, and such material was not observed in the surrounding matrix. We confirmed that the COS, host of the inclusions, consist of symplectitically intergrowth of magnetite and Fe-Ni sulfides.

We obtained oxygen isotopic composition of the COS gain using NanoSIMS. The COS grain has $^{17,18}\text{O}$ -rich composition ($\delta^{17}\text{O} = 159.06 \pm 5.79$ (1 σ) ‰, $\delta^{18}\text{O} = 166.31 \pm 3.18$ (1 σ) ‰) which is similar to the COS grains reported by previous study^[3]. We could not check the difference in oxygen isotopic compositions between the inclusions and the host COS because the inclusions were too small to obtain their compositions.

The inclusions found in this study have not been reported from other COS grains. It is possible that

previous studies could not find the inclusions because most of the inclusions were plucked from the host COS during sample polishing. In fact, many COS grains reported in previous studies contain abundant pores which probably formed by plucking of inclusions. If inclusion is common in COS, it is important to constrain the origin of COS. We will present the results of further TEM analysis of the COS and their inclusions, and discuss the origin of them.

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