The magnetite colloidal crystal in the meteorite formed 4.6 billion years ago

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1. Introduction

Fig. 1 polarized image and BSE image of meteorite thin section.

Meteorite matrix have preserved information on the early solar system (Fig. 1). To date, most of researches investigating the meteorites have been focused on mineralogy, measuring the chemical compositions, isotopic ratios and so on. In the present work, detailed observation was carried out on the magnetite with highly ordered three dimensional, namely colloidal crystals. As is the case with crystal surface or morphology, these aggregates structures also reflected environment in which they formed in the parentbody. Investigating these objects from the view point of the colloidal science and crystal growth, we will provide new valuable information to the planetary science.

2-2 Lattice structure of colloidal crystals

Although magnetite particles usually appear randomly in the matrix (e.g. Fig. 3), there are areas where the size of particles is uniform. Furthermore, they are aligned in a regular periodic 3D structure, and form colloidal crystals. We could observe several types of colloidal crystals in this meteorite. Fig. 4 is one with b.c.c. (body centered cubic) lattice structure comprised by 150nm particles. Fig. 5 is one with f.c.c. (face centered cubic) lattice structure comprised by 200nm particles.

2-3 Characteristics of Rhombic dodecahedron particles

The particles of the colloidal crystal of Fig. 5 is only formed by (110) faces, so it forms rhombic dodecahedron. Fig. 6 indicates why the colloidal crystal can only form f.c.c. structure. It is interesting to note that this particle has the depressed area on certain edge (arrows in Fig. 9 (a),(b)). HR-TEM investigations of the depressed edge exposed mismatch of lattice, which could result in the boundaries of the crystals (c). These morphologies and structures are similar to those of multiple twin particles.

2-7 The Greigite occurs together with magnetite

EDS measurement to magnetite colloidal crystal detects not only Fe and O but also S. Analyzing the high resolution TEM image, these were identified to greigite which is composed by few nm sizes crystalline. The magnetite particles accompany with the greigite in most cases, which indicate the greigite have deep relation in generation of magnetite.

2. Observations and Discussion

2-1 Occurrence of Magnetite

Fig. 2 shows model of aqueous alteration process in meteorite parentbody (Rosenberg et al., 2001). Radiogenic heat melted ice to water, in which nucleation and aggregation of fine magnetite particles took place.

2.2 Observations of Magnetite

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2-5 DLVO curve of magnetite colloidal crystals

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2-8 Possible formation mechanism of magnetite colloidal crystal

Schematic diagram of the possible formation mechanism of magnetite colloidal crystal. At first, greigite which has weak magnetic force has formed. Then, they dispersed in the solution, and form colloidal crystals. Finally, replacement of S to O makes magnetite particles.