Paleomagnetism of individual magnetite nanoparticles in a meteorite using electron holography

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The aim of this study is better understanding of the formation environments of extraterrestrial minerals and thermal history of asteroids in the ancient solar system before 4.6 billion years. We have attempted to apply the electron holography to magnetite nanoparticles extracting from the Tagish Lake meteorite, which experienced negligible alteration and minimal contamination because of its rapid recovery after falling to Earth in 2000 [1]. In the matrix of the meteorite, a lots of magnetite nanoparticles are distributed together with clay minerals [1,2] suggesting formation of these minerals by an aqueous process [3]. We visualized the magnetization of the magnetite nanoparticles using electron holography and found that magnetite nanoparticles have a flux-closure vortex structure [4]. This characteristic magnetic structure allows periodical alignment in three-dimensionally for formation of colloidal crystal of framboidal magnetite [5].

Remanent magnetization of minerals is very sensitive to the formation and experienced environments such as temperature and magnetic field [6]. Based on the bulk magnetization of the Tagish Lake meteorite, for instance, the origin of its magnetic properties has been proposed to be multidomain magnetites with a grain size of 4 - 9 μm [7]. Several reports about paleomagnetic studies of meteorites has been reported in recent years [e.g. 8]. We expected if the paleomagnetic method will be applied by means of electron holography on a nanometer scale mineral in a meteorite, formation and/or thermal history of individual minerals will be elucidated. Here, we show our recent approaches to visualize the temperature dependence of magnetic properties of isolated magnetite from colloidal crystals in the Tagish Lake meteorite and the results of nanometer-scale paleomagnetism. Formation temperature of individual magnetite by thermal aqueous alteration in a parent body of the Tagish Lake meteorite will be determined. In addition, thermal evolution of the parent body (asteroid) of the Tagish Lake meteorite will be estimated using a constrain for the formation temperature of the magnetite based on theoretical calculations, which also allow as to propose the size, age and/or shock event on the asteroid.

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