Efficiency of Magnetic Alignment observed for Ice Ih and Possibility of Alignment in Various earth and space condition

Shun Kanou[1]; Takaaki Abe[1]; Chiaki Uyeda[1]

[1] Earth and Space Sci., Osaka Univ.

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Micron-sized grains bearing spontaneous moment are known to align by terrestrial field; the alignment is the basis to investigate paleo-magnetism, and provides a direct evidence of plate tectonics. The theoretical basis of observing interstellar magnetic field is based on alignment of dust particles. Up to now, only the effects of spontaneous or paramagnetic moments are considered in these phenomena of alignment. A mineral can cause alignment due to anisotropy of magnetic susceptibility 'Delta-chi' even if they contain no spontaneous moment; however its possibility has been ignored for most of the natural material. In the present study, Delta-chi is newly obtained for hexagonal ice (Ih), which is omnipresent in various earth and space regions. Obtained Delta-chi value was as $3.3\text{x}10^{-10}$ emu/g. Diamagnetic anisotropy derives from spatial anisotropy of electron distribution of a crystal. Delta-kai was expected to be negligibly small for ice Ih, because configuration of O-H-O bond in a (Ih) structure was close to regular symmetry. Almost all the solid material in nature has the potential to cause alignment, because it is revealed that even an Ih crystal with highly-symmetrical electron distribution possesses a finite amount of Delta-chi.

A new method to detect small Delta-chi value was developed in order to realize measurement of ice Ih. Detection limit was improved from a level of 10^{-9} emu/g to 10^{-10} emu/g by this method. Period of oscillation t was measured for the rotational oscillation of magnetically stable axis with respect to horizontal field; sample was suspended by a thin fiber of 12 microns in diameter. Delta-chi was obtained with high sensitivity from the gradient of linear t^{-2}-B^2 relationship. Improvement of sensitivity was achieved because contribution of restoration torque of a fiber was excluded in the measurement. It was necessary to confirm whether the new method was capable to detect small Delta-chi value with sufficient precision. A standard sample was newly prepared, which possess small Delta-chi value of the level of 10^{-10} emu/g. A standard sample was produced from two crystal blocks of which had same geometries; they were joined with their magnetically stable axes crossed with an angle of A. In this study, quartz single crystal was used to for preparing the above-mentioned standard sample; Delta-chi of quartz was $2.3\text{x}10^{-9}$ emu/g. The Delta-chi measurement were performed at A=0 degree to 85 degree. Measured Delta-chi values showed fairly good agreement with the calculated value. At A=85 degree, obtained Delta-chi value is $1.8\text{x}10^{-10}$ emu/g. Contribution of paramagnetic anisotropy due to impurity ion was negligibly small for ice Ih, according to measured Delta-chi and T relationship measured between T = 170 K and 240 K. Effect of dislocations on Delta-chi value was small as well. Delta-chi value measured for intentionally deformed samples coincided with the value of high-quality crystal within an error. The above value is the most reliable value at the present time. The present Delta-chi value serve as a basis to investigate field structure in space, for example in a planetary formation region. According to theoretical studies, magnetic field in Young Stellar Object is a driving force of bipolar jet flows associated with this system. Heat caused by reconnection of field around a proto-planetary disk produced calcium-aluminum-rich inclusions (CAIs) and chondrules, according to the so-called 'x-wind model'. The sufficiency of these hypotheses on planetary evolution should be examined by observed field structures. It is expected that field direction is determined from polarimetry data cause by dust alignment. Ice Ih is a candidate of dust component in this area; however magnetic alignment of ice dust cannot be explained in terms of conventional mechanism based on spontaneous or paramagnetic moments.