Magnetic Anisotropy observed for single crystal of hexagonal ice Ih.

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Magnetic alignments of micron-sized grains have provided direct evidence of continental drift; it has been the basis to estimate field structure of interstellar region. Presently, alignments are believed to occur only on material that bears spontaneous magnetic moment or high amount of paramagnetic moment. Recently, rotational oscillations has been observed for various diamagnetic single-crystals that were suspended in static field below 2Tesla[1]. The oscillations are caused by anisotropy of diamagnetic susceptibility delta-kai, which arise from anisotropy of molecular orbital in a crystal.

In the case of ice Ih, c-plane showed rotational oscillation with respect to direction of field [2]. By observing period of oscillation for ice Ih single-crystal, small delta-kai at the level of 10E-10emu/g was obtained for the first time. delta-kai value of ice was previously reported by Lonsdale to have an order of magnitude of 10E-9emu/g. Here c-axis was concluded to be a magnetically stable axis. In a conventional delta-kai measurement, a sample was suspended in a horizontal field B with a rigid fiber. Here direction of magnetically stable and unstable axes is set in the horizontal plane, and delta-kai between the two axes are measured. Sensitivity of delta-kai was limited by a restoration torque of the fiber. In the present study, sensitivity was improved considerably by measuring the above-mentioned oscillation of the principle axis with respect to B, in a condition that torque of the fiber was negligibly small compared to the magnetic torque.

The obtained delta-kai value provides information to understand the 3-dimensional configurations of molecular orbital in an inorganic crystal. Origin of delta-kai above 10E-9emu/g were quantitatively explained by assuming a constant uniaxial delta-kai on individual bonding orbital. Diamagnetic anisotropy of a single bonding orbital was determined from compiled experimental data, and anisotropy of an arbitrary oxide can be predicted by assigning the above mentioned anisotropy on individual bonds in the crystal. Here bond configurations in the crystal are directly obtained from atomic position data. It is noted that calculated delta-kai of ice Ih do not agree with the measured result. Quantitative comparison between measured and calculated delta-kai is required for various oxides with high symmetry, namely a rutile, a wurtzite or a perovskite structure, in order to clarify the origin of small diamagnetic anisotropy at the level of 10E-10emu/g.

Magnetic alignment of a small particle with mass M dispersed in fluid at temperature T proceeds by a balance between anisotropy energy induced in the particle and energy of Brownian motion, as proposed by Langevin and Curie. It is deduced from obtained delta-kai value that almost full alignment is achieved below B = 3 T for ice Ih grain of 2 micron in diameter, when it is dispersed in fluid at T = 273 K. New types of magnetic alignment may be recognized in nature, since potential of alignment is evident for major natural minerals in various natural conditions [3]. For example, it provides a basis to determine field structures from observed polarimetry data in a proto-planetary disk. As mentioned before, magnetic field plays a major role in planetary formation. [1] Uyeda C et al.: Appl. Phys. Lett. 86, 094103- 1-3 (2005). [2] J. Phys. Conf. Ser. 51 466-469. [3] Uyeda C et al:, 60, 3234, (1991).