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Free Translation of Ice Ih Induced by Field Gradient Force

UYEDA, Chiaki[1*]

[1]Graduate School of Science Osaka University

Magnetically induced translation was newly observed for crystals of mm-sized ice (Ih) in micro-gravity condition produced by a chamber-type drop shaft. Here the crystals were released in an area of monotonously decreasing static-field filled with N2 gas medium (P=10E5 Pa). It was deduced from a Newton equation that terminal velocity of the translating ice outside the field was independent to mass m of crystal; in a given field distribution, the velocity is uniquely determined by intrinsic diamagnetic susceptibility (per unit mass) of the material. Value of susceptibility obtained from observed terminal velocity agreed fairly well with the published value of ice Ih; 8x10-7emu/g. Relationship between susceptibility and m value of crystal was experimentally examined in a range of m = 30-5 mg. No sign of m dependence was seen for the measured susceptibilities above the extent of experimental error. The above two results indicated that the observed translation of ice followed the assumed Newton equation. The experimental setup developed in this work will become the basis to observed magnetic ejection of other volatile solids that are the major solid components in the outer solar system; namely, carbon-dioxide, ammonia, or methane. The above translation observed in micro-gravity can be applied to detect susceptibility of a single small particle, because the method is not affected by interferences of the sample holder used in conventional methods; the new method is also free of mass measurement. Provided that sample motion is observable, susceptibility is obtained for a small sample irrespective of its size [2]. Based on the obtained efficiency of measuring susceptibility, possibility of constructing a compact apparatus of material identification is discussed, which can analyze the volatile dust particles in a simple manner during a mission orientated toward the outer solar-system.

The above translation was previously observed for popular diamagnetic materials such as calcite, corundum, forsterite, graphite and alpha-quartz[1]. Magnetic orientation of magnetically stable axis with respect to field direction was reported as well for the above crystals including ice; the rotation was caused by diamagnetic anisotropy. Possibility of magnetically-induced dynamical motions, namely translation & rotation, has been recognized only on materials that possess spontaneous moments or strong para-magnetic moments. A chamber type drop shaft was developted to study the procedure of releasing the ice sample in our home laboratory. The compact drop shaft was recently adopted in an educational program performed at a senior high school; there, a two fold capsule system was introduced to improve the level of micro-gravity[2].

[1] C.Uyeda et al, J.Phys.Soc.Jpn. 79 (2010) 064709
[2]Kasugaoka Senior High School (Osaka-Pref.) JpGU meeting 2011 & 2012. Union session, Poster presentations by senior high school students.

Keywords: chamber type micro-gravity system, ice Ih, magnetic ejection, diamagnetic susceptibility, magnetic orientation, material identification