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Nondestructive characterization of single primitive grains by observing magnetic ejection in microgravity

Keiji Hisayoshi[1*], Shun Kanou[1], Chiaki Uyeda[1]

[1]Graduate School of Science,Osaka Univers

A new principle is proposed for the identification of a single grain sample, which is based on a magnetically-induced motion recently found on diamagnetic solids. Field-induced dynamic motions of solid substance are publically recognized only for materials that contain spontaneous magnetic moments. The motions are categorized into two types, an attractive force caused by field gradient and rotation due to a magnetic torque; the first category is familiar by magnetic separation of magnetite grains, while the second is well known by rotation of compass caused by terrestrial field.
Free translational motion caused by repulsive field-gradient force was recently observed for a corundum crystal released in microgravity [1]. In a given field gradient, acceleration of translation was uniquely determined by magnetic susceptibility of corundum. It is expected that characterization of a small diamagnetic particle is realized from the above-mentioned motion, since an intrinsic susceptibility is assigned to an individual material according to a data book that compiles the published values [2].
In the present work, translational motions were examined for mm-sized crystals of forsterite, diamond, silicon carbide, and graphite, in order to examine the above possibility of characterization. A permanent magnetic circuit (NEOMAX X-1466) was adopted in the experiment, which produced homogeneous field of B=1.18 T in an area of 1.5cm in diameter at center of pole pieces. Initial position of the samples was located just out side this area. The magnet was loaded on a drop capsule at Micro Gravity Laboratory of Japan (MGLAB, Toki, Gifu, Japan) [3]. The translational motion of sample was visually observed using a high-vision video camera. According to a motional equation, value of acceleration was expected to be proportional to B(dB/dx) and susceptibility of material. Therefore, acceleration and B(dB/dx) were measured at several sample positions in a single turn of experiment; linier correlations were obtained between the two parameters for all the samples. Susceptibilities that were determined from the gradient of the above relationship agreed fairly well with its published values [2]. Hence efficiency of the above method to obtain diamagnetic susceptibility was quantitatively confirmed. Free translation of ordinary diamagnetic substance, caused by small field gradient of a permanent magnet, does not appear in previous literatures. In principle, diamagnetic susceptibility is detected on limitlessly small sample by the above method, provided that motion of the sample is observable. This is because the new method is free of a sample holder and mass measurement; moreover the motion is based on a simple motional equation that is composed of a magnetic term and an inertia term [4]. Conventional magnetization measurements in normal gravity are generally prevented by background signal of sample holder when size of sample is smaller than 1mm in diameter.
A simple and nondestructive method to identify the individual grain particles may serve as a useful tool to carry out a comprehensive anatomy of primitive meteorite. It is seen that the present method is capable of identifying pre-solar grains that are commonly found in the meteorites, since the 4 materials measured in the present work are major materials compose the grain. The susceptibility values observed in the present work ranged between susceptibility=$-2x10^{-7}$and$-5x10^{-6}$emu/g; almost all the published susceptibility values of organic materials distribute within this

range [3]. Hence identification is possible as well for other material that is included in the meteorites, namely for the carbonaceous matters that requires further characterizations.

References
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