The development of apparatus to separate and identify the volatile solids from its translation caused by a magnetic field gradient

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A new principle to separate and identify volatile solid particles, using an area of monotonically-decreasing magnetic-field, was proposed and examined; the principle was based on a setup that was designed in a previous study using a microgravity condition [1]. Using the new system, magnetic separation was realized for the first time on an ensemble of heterogeneous particles that included solid H_2O and CO_2; the former setup could conduct the experiment only at room temperature. Furthermore, the material of an unidentified particle can be estimated from the value of magnetic susceptibility that is obtained from the velocity of the translating particle. It is expected from the above results that the material abundances of heterogeneous solid particles that exist in the low temperature regions in the outer solar system are determined in a simple manner without destructing sample, as it is necessary to survey the material distribution of volatile particles over a wide region.

Many of the solid materials that exist in nature are composed of diamagnetic materials which do not exhibit saturated magnetization; these materials are generally believed to be magnetically inert. However, a small magnetization is induced in the opposite direction of an applied magnetic field *B*; this magnetization is proportional to *B*, mass of particle *m* and an intrinsic magnetic susceptibility (per unit mass) assigned to a material. Accordingly, terminal velocity of particle outside the magnetic field does not depend on *m*. It is expected from the above properties that an ensemble of heterogeneous diamagnetic particles can be separated into different groups of materials when they translate in a direction of decreasing field [1]. It is noted that the monotonically decreasing field to realize the separation can be produced by a pair of small NdFeB plates.

Using the above separation principle, a mass ratio of a binary-mixture sample is directly obtained from its susceptibility χ. The χ value of a binary sample (composed of matter 1 and 2) is described as $\chi = f\chi_1 + (1 - f)\chi_2$···(1), where the mass ratio of matter 1 is determined as, $f = m_1/(m_1 + m_2)$; here m_i describes mass of the matter i, and χ_i describes the susceptibility of the matter i (i=1, 2). Accordingly, when the susceptibilities of the two end-members, χ_1 and χ_2, are known, the mass ratio f is uniquely determined by susceptibility χ of binary-mixture. Advantage of the above method is to be able to estimate efficiently on the spot histograms of the mass ratio of binary-mixture particles existing on an investigated area and the existence frequency. Using the conventional analytical methods, multistage operations are required to obtain the f values; specifically, the particles must be sliced into sections, and the elemental abundance of the cross sections should be analyzed by a refined microprobe system. In contrast, proposed method can determine the mass ratio only by observing the velocity of magnetic translation, and do not require other physical parameters such as the mass and the volume of particles.

In the experiment, the NdFeB plates were fixed in an insulating container together with the homogeneous particles. Then the container was filled with dry ice blocks to maintain temperature at T=198 K, and was installed inside a compact drop box. A hi-vision camera was set to observe the translation, and susceptibility is calculated by obtained terminal velocity [1]. Microgravity condition is produced inside the drop box as it dropped through a short shaft (180 cm in height, duration of microgravity < 0.5 s). Based on the numerical data obtained in the experiment, the validity of the separation principle is examined,

and the possibility of applying the system in a remote sensing mission is discussed.

[1] Hisayoshi, Uyeda & Terada (2016) Sci Reps 6 38431.

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