Magnetic separation and identification of low-temperature solid particles using their translation caused by a pair of small permanent magnets

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Most solid particles in nature are categorized as diamagnetic or weak paramagnetic materials; they are commonly believed to be magnetically inert, and cannot attain strong magnetization to cause specific magnetic motions at practical field intensity. Indeed, strong magnetic field above the level of 10 T were applied in previous studies to induce magnetic levitations. A method to separate solid particles by a field gradient produced by small NdFeB magnets was recently proposed and experimentally approved using a setup operated in microgravity condition [1]. By improving this system, magnetic separation was realized on volatile solid particles, namely H2O and CO2, for the first time [2]. In addition, it was possible to estimate the material of the particle in a non-destructing manner by comparing the experimental value of magnetic susceptibility with a list of published values [1][2]: here the susceptibility was obtained from the velocity of the translating particle without the knowledge of particle mass.

In the present experimental present setup, a pair of small NdFeB plates was attached in a double glass container. A microgravity condition is produced inside the box by free fall from a height of 180 cm. An ensemble of heterogeneous particles translates and separates by magnetic field gradient in free fall. The Hi-vision camera observed the translation and susceptibility is calculated by obtained terminal velocity [1]. The obtained susceptibility of the particle is compared with literature data and materials of particles are estimated.

The field-induced translational motions realized in μg condition can be utilized in various space missions in future; this is because the small but rigid apparatus can separate and identify the heterogeneous particles that is expected to be collected in an on-site mission. One of the major purposes to perform space explorations to the outer solar system was to identify the solid materials that are observed on satellite surfaces or ring. It is concluded by recent observation that the solid particles were mainly composed of ice (Ih) with high purity; previously it was considered that the icy particles of the rings contain significant amount of rock-forming silicates. Hence, for a future task, quantitative information of the minor silicate composition included in the icy particle is required in studying the origin of the Saturn rings.

An efficient method that can non-destructively identify the components of a heterogeneous aggregate sample is desired in various research fields of material science. Using an infrared optical analysis, for example, the material composition of the particle interior is difficult to determine when the sample is larger than 100 μm in diameter. In the case of a conventional mass spectrometer, it is difficult to identify the composition of solid particles without destructing the sample. Although various microprobe devices are effective in performing refined survey on aggregate samples, it is difficult to conclude by these methods whether small particles included in the aggregate are completely discovered and identified without omission. In such cases, the particles should be definitely separated into groups of different materials before performing refined analysis [1-3]. Note that the present proposal of magnetic separation can overcome the abovementioned limitations of the conventional methods, and in future, it may serve as a standard pretreatment tool of material analysis.

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

[2] Yamaguchi, Hisayoshi, Uyeda & Terada (2017) J. Phys., Conf. Ser.903, 012026.

[3] Hitomi, Yamaguchi, Hisayoshi, Uyeda (2018) Planet Space Sci., available online.

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