Efficiency of material separation caused by magnetic field in outer space recognized for solid particles in general

*Chiaki Uyeda[1], Kentaro Terada[1], Keiji Hisayoshi[1]

1. Institute of earth and Space Science Graduate School of Science Osaka University

Magnetic field gradient and dust particles coexist in various regions of galactic space. Although the field intensity in these regions are considerably low compared to the experimental conditions available on earth, the immersive microgravity duration in these area may cause specific motion of solid particles, and the translation may cause material fractionation that are observed in these regions. Magnetic separation is generally caused by a magnetic potential induced in the solid particle, and was conventionally used to collect ferromagnetic, ferrimagnetic or strongly paramagnetic materials. Whereas, it was believed that most of the existing material (i.e. diamagnetic & paramagnetic material) required ultra-strong field intensity above 10 Tesla. Field-induced translation was recently observed for single diamagnetic particles released in an area of a monotonically decreasing field, and values diamagnetic susceptibility per unit mass was detected from a small sample;[1][2] in these experiments, the grain was allowed to translate freely in a diffuse area using microgravity conditions. Based on the same principle, we found that ensembles of heterogeneous particles are separated into fractions using a neodymium hand magnet (*go to* YouTube" Magnetic separation of general solid particles realized by a permanent magnet" *for the movie*) [3] .The ensemble consisted of diamagnetic bismuth, diamond and graphite particles, as well as two paramagnetic olivine.

The setup to observe the separation was installed in a wooden box that was attached to the top position of a drop shaft (length ~1.5 m). The duration of the microgravity condition was approximately 0.5 s. With the beginning of microgravity, the a carbon sample stage inside the stage-holder was levitated, which was effective in releasing the grains in a diffuse area; here the stage was spontaneously levitated by a small field gradient applied in the vertical direction. In previous studies, it was technically difficult to release a substance in a diffuse area in μg conditions. The separation of weak magnetic material was realized because the terminal velocity of the particles that translated in an area of B=0 was uniquely determined by the intrinsic susceptibility of the material and also by the field intensity at the initial sample position; the velocity was independent to mass of particle. This relationship was directly deduced from an energy conservation rule. The result achieved here is against the generally accepted notion that ordinary solid materials (i.e. diamagnetic and paramagnetic materials) are magnetically inert. In the diffuse conditions of outer space , the effectiveness of the field-induced separation would be more efficient because the effects of viscous drag, friction and gravity are negligible. Recently the mass independent property of magnetic translation was also confirmed for ferromagnetic and ferri-magnetic grains, namely in iron, nickel and ferrite. This means that proposed principle of material separation is confirmed for all categories of magnetic materials.

References

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