Separation and non-destructive identification of diamagnetic paramagnetic particles using translational motion caused by magnetic field gradient in microgravity

*Keiji Hisayoshi[1,2], Chiaki Uyeda[1], Kentaro Terada[1]

1. Dept. of Earth and Space Science, School of Science, Osaka University, 2. Otemae Senior High School of Osaka Prefecture

We previously developed a new magnetization measurement method using field-induced translational motion in microgravity space, and proposed a material identification based on this translation [1][2]. Solid particles released in a dilute space cause translational motion in the magnetic field due to its magnetic potential. Since this motion derives from a field-induced body force, its acceleration ***a*** uniquely depends on the magnetic susceptibility assigned to the material; ***a*** is independent of the mass of the particle. Therefore, by comparing the obtained magnetic susceptibility with its published value, it is possible to identify the material of a single particle without destructing it. We have confirmed that the magnetic susceptibility obtained by the translational motion of the sample agree with the published value for various diamagnetic particles having the size of mm ~ sub-mm. Magnetic susceptibility was also obtained from translational motion in volatile solids, namely H_2O and CO_2. Based on the principle, ensemble of diamagnetic particles and paramagnetic particles with different susceptibilities were simultaneously released from a certain position in the magnetic field. As a result, we were able to separate, collect and identify the particles by the variance of particle velocity [3].
Microgravity was generated using a short drop shaft. The length of the shaft is 1.8 m. The effective microgravity duration is about 0.5 seconds. The device for observing the translation was set in a box of 30 ×30 ×20 cm. The device consists of a small NdFeB magnetic circuit (B <0.8 T), vacuum chamber, lighting, battery and high speed camera. The inner pressure of vacuum chamber was reduced to ~100 Pa to eliminate the effect of air resistance.
An ensemble of heterogeneous particles was set at a position located in an area of monotonically decreasing field. The particles were composed of three diamagnetic materials and two paramagnetic materials were released in the microgravity space at the maximum value in the magnetic field gradient. Diamagnetic materials minerals translated out of the magnetic field, paramagnetic minerals translated in the magnet center direction. Particles were supplemented as different groups on a collection plate coated with two silicon greases set in both directions (YouTube: Magnetic separation of general solid particles realised by a permanent magnet). In addition, the magnetic susceptibility of each sample was found from the velocity of translational motion, which agreed with the published value, respectively [3].
So far, field-induced separation and extraction of solid is recognized in materials that bear spontaneous magnetization. The present results strongly indicate that the separation can be expanded to general solids using a hand magnet. The potential of this method as an analytical technique is comparable to that of chromatography separation because the extraction of new solid phases from a heterogeneous particle ensemble will lead to important discoveries about inorganic materials.

Reference
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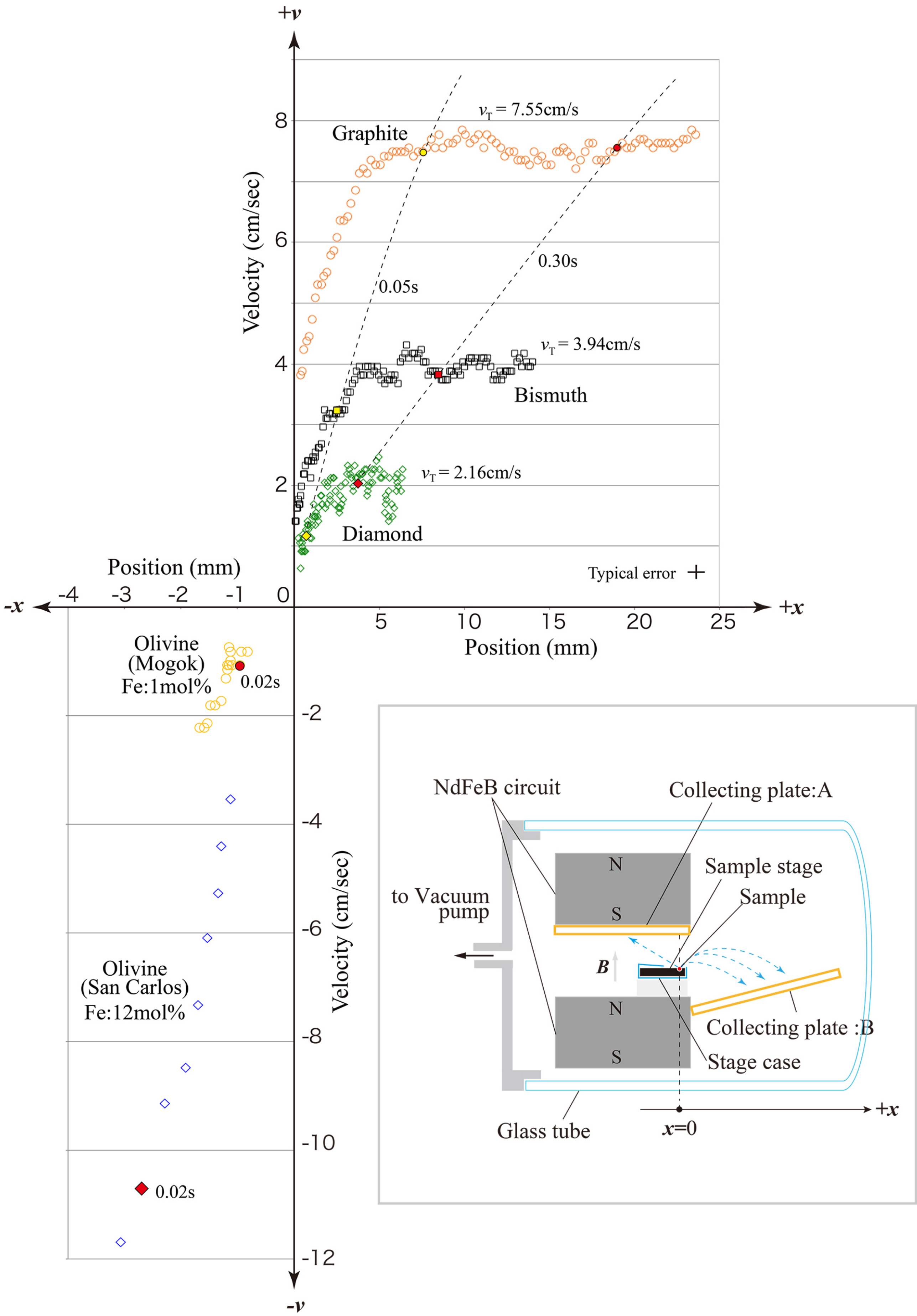
Keywords: magnetic separation, non-destructive identification, microgravity, magnetic translational motion, diamagnetic, paramagnetic


+v
Velocity (cm/sec)
v_T = 7.55cm/s
Graphite
0.30s
0.05s
v_T = 3.94cm/s
Bismuth
v_T = 2.16cm/s
Diamond
Typical error
Position (mm)
-x
+x
Olivine (Mogok) Fe:1mol%
0.02s
Olivine (San Carlos) Fe:12mol%
0.02s
-v
NdFeB circuit
Collecting plate:A
Sample stage
Sample
to Vacuum pump
B
Collecting plate :B
Stage case
Glass tube
x=0
+x