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Nondestructive characterization of a single micron-sized primitive-grain realized by magnetic ejection in microgravity

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A new principle is proposed for the characterization of a single grain sample. This principle is based on a translation induced by a magnetic field-gradient force that was recently found on diamagnetic solids [1][2]. A single mm-sized sample was released in an area field gradient that was located in microgravity condition. According to a motional equation of translation, acceleration of sample was uniquely determined by intrinsic magnetic susceptibility of the material in a given field distribution. Hence susceptibility of the sample was detected by observing field-induced motion of the sample. Since a published value of diamagnetic susceptibility exist for a solid material, the identification of material is possible by comparing the measured susceptibility data with the compiled list of published values. Conventional magnetization measurements in normal gravity are generally prevented by background signal of sample holder when size of sample is smaller than 1 mm in diameter. The mass measurement of the sample is difficult below the level of 100 micro grams . In contrast, it is expected that the proposed method can measure susceptibility of a single grain with limitlessly small size, provided that the observation of the grain motion is possible; material identification of the small becomes possible as well.

The conventional facilities of microgravity are not suitable for a routine analysis such as the present measurement of susceptibility. This is because the facility system requires a long machine time; its running cost is considerably high. Therefore, a compact microgravity system, which can be introduced in an ordinary laboratory, was newly developed. The length of the drop shaft is 1.5m, and the duration of microgravity time is 0.62 second. The experimental apparatus was set inside a rectangle box which had a size of 30cmx30cmx20cm. The vacuum chamber equipped with an electric actuator, sample releasing signal reception device, the sample holder controller, the magnet, the battery, and the high-vision video camera are installed in the box. The sample is released in the field-gradient produced by a by a magnetic circuit composed by a NdFeB permanent magnet. Maximum field intensity of the circuit was 0.7 T. The box was attached to the sealing of the laboratory room by an electromagnetic lock system. The free fall of the box started shortly after the power supply of the lock was shut down. Image of sample translation was recorded by the HV camera.

In the present work, translation was observed for small particle as small as 50 micron for graphite and the diamond. The spatial and time resolution of the present system can be improved by introducing a macro-lens, and by recording the image by a high-speed photography. The above mentioned improvements is expected to identify the sample of about 20 micron. If a single small particle can be identified nondestructively, the possibility of analyzing individual particle that compose primitive meteorite is expected to increase drastically. The observed magnetic susceptibility is in the range of -5x10^{-6}emu/g from -2x10^{-7}. It is expected that the diamagnetic susceptibility of the organic matter contained in the meteorites distribute in this range.

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[2] C. Uyeda, K. Hisayoshi and S. Kanou: Jpn. Phys. Soc. Jpn. 79 (2010) 064709

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