Magnetic anisotropy observed in bulk & rod-shape amorphous silica and its implication to the origin of dust alignment

Naoya Okimoto, Chiaki Uyeda, and Keiji Hisayoshi

Institute Earth & Space Science, Graduate school of Science, Osaka University, Japan

Anisotropy of paramagnetic susceptibility $\Delta\chi$ (per unit mass) was detected in the surface area (0 mm< depth < 0.5 mm) of an synthesized amorphous silica; the material was synthesized by cooling a silica melt (maximum temperature < 1260 K) at a cooling rate of ～7 K/s. The anisotropy is considered to derive from the small amount of ferrous ion (0.06 wt %) included in the starting material. The produced silica serves as a reference sample to investigate the possibility of dust alignment in various galactic regions anisotropy based on magnetic anisotropy energy. Up to now, the possibility of magnetic alignment based on anisotropy energy is not considered on a amorphous silica in the researches of magnetism because they are believed to be magnetically isotropic.

A setup developed to observe the field-induced rotational-oscillation of a bulk sample in a short μg condition to observe the magnetic separation [2] was reformed in the present study. The sample chip separated from the surface of the bulk silica sample was set on a holder and installed in a transparent glass tube that was attached between the N and S pole of a compact NdFeB circuit. The magnetic line of force at sample position was normal to the tube. The above setup was installed in a wooden box (30 x 40 x 40 cm). This box was attached to an electromagnet of a short drop shaft that had a length of 1.5m [2], and the free fall of the box started by cutting off the power supply of the electromagnet. The sample piece was successively released from stage to the μg space by an attractive field-gradient force produced by a field gradient between the N and S pole [3]. In a μg experiment, it was generally difficult to release a small sample a diffuse area because of various attractive forces. The observed period of oscillation followed the formula of harmonic oscillation, and magnetic anisotropy was obtained without the necessity of measuring the mass of sample [3].

The $\Delta\chi$ value observed at the silica surface, was 1.1×10^{-7} emu/g, although below a depth of ~1mm, $\Delta\chi$ was diminished to 3.9×10^{-8} emu/g. This variation of $\Delta\chi$ between surface and interior was comparable to those previously observed at the surface of two tektites, namely Moldavite [3] .

The cause of the the enormously enhanced anisotropy that appeared at the silica surface is an open question. In order to solve this problem, a structural anisotropy at atomic scale should be experimentally identified. We therefore performed Electron Spin Resonance (ESR) in the above sample plates, and angular dependence with uni-axial symmetry was obtained with its principle axis nearly normal to the silica surface. The result strongly indicates that structural anisotropy at atomic scale can be produced by rapid cooling. The comparison between the $\Delta\chi$ data and the ESR spectrum, as performed in the present report, will provide useful information to study the origin of the anisotropy that appeared at the silica surface. Further information will be obtained by changing the experimental conditions in synthesizing the samples, for example, concentration of paramagnetic ion, maximum temperature of silica melt as well as its cooling rate. The anisotropy is now measured in synthetic fiber samples (diameter ~ 50 microns) produced from the above silica melt, which will serve as a direct reference of the rod-shaped dust particles that is commonly assumed in the interstellar regions.

References

[1]Uyeda, C., K. Hisayoshi, and S. Kanou, *Earth Planets Space*, **62**, 99-103, 2010.
[2] K. Hisayoshi, Uyeda, C., K.Terada, *Sci. Rep*, **6,** 38431, 2016.
[3] Yokoi, M. et al, *Planet., Space Sci.,* **103**, 1- 2014.