

## Efficiency of Alignment Detected for Ordinary Nonmagnetic Material using a Hand Magnet and Possibility of Alignment in Nature

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Up to now, magnetic alignment of small solid particle is considered to occur only for materials that possess a spontaneous or a paramagnetic moment. A solid body may cause magnetic alignment by anisotropy of diamagnetic susceptibility  $\Delta\chi$ , however the property has not been studied intensively both in basic and applied science.

Here we report that ordinary solid crystals without spontaneous magnetic moment can cause rotational alignment at low field of 0.01 T produced by a horseshoe magnet.  $\Delta\chi$  above  $10^{-8}$  emu/g was obtained from period of rotational-oscillation of the sample, which was suspended by a thin polyaramide fiber of 12 microns in diameter. Measured  $\Delta\chi$  was consistent with published value for calcite, forsterite, muscovite, gypsum, graphite, Rochelle salt, talc and urea.  $\Delta\chi$  can be detected effectively over a immense number of solid materials, since many of the unmeasured values are expected to exceed  $10^{-8}$  emu/g according to a model based on electron density distribution. The fact that most of the nonmagnetic crystals show rotational oscillation by a hand magnet contradicts with the common conception that ordinary solid materials show magnetic alignment only at ultra-high field intensity above 10T.

Sensitivity for measuring  $\Delta\chi$  can be improved drastically by realizing the oscillation in microgravity, where the fiber itself is deleted; oscillations were achieved for corundum and quartz at 1.3T. Higher sensitivity is necessary to obtain small  $\Delta\chi$  values. This can be done by increasing length of measurable period of oscillation in a parabolic flight or in an orbital laboratory. High sensitivity is required to detect  $\Delta\chi$  of crystals which have high crystal symmetry, such as wurtzite or perovskite structure. Property of alignment may be recognized for almost all the solid materials, with the exception of crystals with cubic symmetry, when sensitivity of  $\Delta\chi$  reaches the level of  $10^{-11}$  emu/g in a parabolic flight.

Possibility of magnetic alignment caused by  $\Delta\chi$  may be considered both in natural and artificial conditions, since most of the solid materials are newly conceived as magnetically active materials. It is well known that alignment of a small particle dispersed in fluid is explained by a balance between anisotropy energy induced in the particle and energy of Brownian motion. Here alignment is controlled by 3 parameters,  $\Delta\chi$  (per unit mass), temperature and mass of particle. This means that partial alignment of a nonmagnetic crystal grain is possible by terrestrial field at the surface, provided that the crystal has a sufficient size. Alignment is also proposed for pre-solar grains that exist in envelopes of Asymptotic Giant Branch (AGB) Stars, since polarimetry deriving from dust alignment was recently reported in this region. Measurements of  $\Delta\chi$  were performed on diamagnetic SiC, forsterite and graphite for the purpose of detecting field intensity around AGB Stars; these materials are the major components of pre-solar grains contained in primitive meteorites. Theoretically deduced field-intensity of this region has the level of  $B = 0.1-0.3$  T. Partial alignment is expected at this field intensity for crystal grains of the measured materials according to a calculation based on observed values of the diamagnetic anisotropy. At present, field intensity has not been determined from observation for most of the stars, and the above-mentioned experiment can be the basis of such observations.