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Magnetic activity found in ordinary rock forming minerals due to paramagnetic and diamagnetic anisotropy

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Magnetic alignment of a mineral grain is believed to occur only when it bears spontaneous magnetic moment or paramagnetic moment with high concentration. During the last two decades, alignment was observed at low field intensity for many of the rock forming mineral which do not possess high concentration of magnetic ions[1]. Anisotropy of diamagnetic or paramagnetic susceptibility was the origin of these alignments [2].

Magnetic alignment of a small particle dispersed in fluid medium at temperature T proceed under a balance between anisotropy energy induced in the particle and energy of Brownian motion. The mechanism was proposed by Langevin and Curie however degree of alignment remained below a level of 10E-6. During the last two decades, almost full alignment had been reported for organic particles in a strong field above several Tesla. Quantitative analysis on alignment process was realized by measuring mineral grains of kaolin, muscovite and phlogopite[1]. It was confirmed that alignment was controlled by three parameters, namely magnetic anisotropy per unit mass, temperature and mass of particle. Magnetic anisotropy of a material is described by a sum of diamagnetic anisotropy and paramagnetic anisotropy.

Recently, origin of diamagnetic anisotropy was studied for oxide crystals based on the above-mentioned experimental data. It was concluded that the anisotropy originated from preferential orientation of bond direction with respect to a magnetic principle axis of crystal. Accordingly a material with high crystal symmetry was expected to posses small anisotropy below 1E-9emu/g. Paramagnetic anisotropy is a dominant factor with respect to diamagnetic anisotropy in an actual material. This is because natural and synthetic materials usually contain finite amount of paramagnetic impurity ions. For example, paramagnetic anisotropy was as large as 10E-5 emu/g when concentration of ferric ion was 1 wt percent for most of the natural silicates.

Alignment of nonmagnetic particles has been recognized as a promising technique to develop functional material. A certain crystal axis of a micron-sized crystal may posses high functionality on elasticity, on electric conductivity or on chemical activity; the functionality is preserved in a crystal-grain aggregate when axes of grains are orientated in one direction. Various types of magnetic effect on nonmagnetic mineral may be proposed in various cosmic and terrestrial conditions based on alignment experiments preformed in laboratory. For example, cause of dust alignment in planet formation region can be understood from experiment on grain alignment at low temperature below T=100K performed for micro-crystal of forsterite and enstatite; these minerals are known to be major components of dusts in the above region. Cosmic field is a major factor that control evolution of stars and planets; field directions are estimated from polarimetry data that are caused by alignment. Mechanism of dust alignment is not understood in the dense region. Hence, the above-mentioned experiment may serve as a basis to estimate field structure from the polarization data in planetary formation region[3]. Dust alignment is also applicable in estimating field direction of star envelopes having temperature above 1000 K. Spontaneous moments is usually lost at this temperature. Magnetic alignment of solid body is measured above 1000K for SiC, forsterite and graphite, which are components of pre-solar grains produced in envelopes of Red Giants. Partial alignment is expected for the minerals at field-intensity that is theoretically predicted for envelop which is 200G. Magnetic field intensity of ordinary stars can be determined for the first time.

[1]C.Uyeda et al: Phys. Chem. Minerals, 20 369,(1993).[2] C.Uyeda et al: Appl. Phys. Lett., 28, 094103, 2005.[3] C.Uyeda et al: Astron. Astrophys. 400. 805 (2003).