Magnetically active properties detected for oxide minerals in general at low field and innovation of functional materials

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A mineral can cause magnetic alignment due to anisotropy of magnetic susceptibility Delta-chi even if they contain no spontaneous magnetic moments[1,2]. However, existence of Delta-chi is not recognized for most of the minerals at present. Two methods are newly developed to accumulate the unmeasured Delta-chi effectively. Oscillation of a magnetically stable axis of a crystal with respect to a horizontal field is observed in the methods without including effect of fiber suspending the crystal. The restoration torque of the fiber was a standard in measuring Delta-chi in the conventional methods. Delta-chi above the level of 10^{-8} [emu/g] are obtained from the period of oscillation, induced at a low field of 0.11 T produced by a horseshoe magnet[3]. Measured Delta-chi values are consistent with the published values for various popular crystals such as biotite, calcite, enstatite, forsterite, graphite, muscovite, talc and urea [1]. Delta-chi exceed level of 10^{-8} [emu/g] for various unmeasured minerals according to a model proposed on the origin of anisotropy [2,4]. Hence Delta-chi can be accumulated effectively over an immense number of unmeasured mineral at various facilities that are not equipped with an electromagnet.

Higher sensitivity is required to accumulate small Delta-chi of materials which have high crystal symmetry, such as wurtzite or perovskite structure. It was pointed out that sensitivity of Delta-chi is improved considerably by realizing oscillation in microgravity, where the fiber itself is deleted [5]; oscillations are achieved for calcite, KDP, gypsum, graphite, Rochelle salt and urea at B=1.3T. Sensitivity is improved even more by increasing measurable period of oscillation in a parabolic flight or in an orbital laboratory. Magnetically active property may be recognized for almost all the minerals when sensitivity of Delta-chi reaches the level of 10^{-8} [emu/g] by the above-mentioned experiments. The nature of spontaneous moment was recognized long ago by a rotational oscillation of a compass due to terrestrial field, which led to the invention of important magnetic devices, such as an electric generator, a motor or a memory disc. Significant rotational motions of ordinary mineral seen in the measurements may induce new devices in various research fields which are not related to magnetism at present. Various effects caused by Delta-chi are reported in the field of material science. A certain axis of a grain may posses high functionality, for example, on elasticity, electric conductivity or chemical activity; the functionality is enhanced in a grain aggregate when the axes of the grains are orientated in one direction. It is believed that strong field above several Tesla is used in these studies, and number of material studied in this field is limited. It is desirable that alignment is achieved at low field when practical application is considered. Alignment of micro-crystal is achieved below one Tesla when Delta-chi is above the level of 10^{-8} [emu/g]; this field is produced by a permanent magnet without introducing an high-costing field generator [6]. It is noted that most of the inorganic materials posses Delta-chi of the above-mentioned level since they contain paramagnetic ions above 0.001mol % in many cases. Hence most of the solid material can be a candidate of a magnetically active material at practical low field.

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