How to Find and Synthesize New Multiferroics showing strong Magnetoelectric Coupling

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Magnetoelectric multiferroics are old but emerging class of materials that combine coupled electric and magnetic dipole order. In these materials, ferroelectric and magnetic ordered states coexist or compete with each other. The interaction leads to a so-called magnetoelectric effect, which is the induction of magnetization by an electric field or electric polarization by a magnetic field. The magnetoelectric effect has attracted much interest for a long time, as the coupling between the magnetism and ferroelectricity can provide an additional degree of freedom in 'magnetoelectric' device design. However, there have been no applications using ME couplings developed to date, due mainly to materials limitations and the small magnitude of the magnetoelectric interaction.

In 2003, a new class of multiferroics such as $TbMnO_3$ has been discovered. These systems exhibit gigantic ME effects accompanied by a magnetic phase transition into a spiral magnetic ordered phase [1]. Thus, the spiral magnetism is the key to understanding the ferroelectric and ME properties in these systems. In spiral magnets, inversion symmetry is broken owing to magnetic order, and some spiral-ordered structures such as a cycloidal one make the system polar. This means that a magnetic order can induce ferroelectricity. The ferroelectricity in the new class of multiferroics can be explained in terms of this scheme. Because spiral order often arises from the competition between nearest-neighbor and further-neighbor magnetic interactions, systems containing competing magnetic interactions (spin frustration) are promising candidates for multiferroics. On the basis of this strategy several new multiferroics related to spiral magnetic orders have been discovered in the past few years. In this lecture, I introduce our strategy to find and synthesize new multiferroics showing strong ME coupling and/or high ME performance such as room-temperature operation [2].

References:
[1] T. Kimura, "*Spiral magnets as magnetoelectrics*"Annu. Rev. Mater. Res. 37, 387 (2007).
[2] T. Kimura, "*Magnetoelectric hexaferrites*", Annu. Rev. Condens. Matter Phys. (to be published).