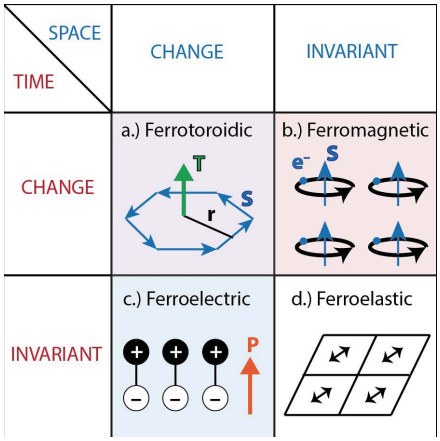
The Fourth Ferroic: Ferrotoroidic Materials and Spherical Neutron Polarimetry

Stephanie Gnewuch, Jacob Tosado, and Efrain E. Rodriguez*
Department of Chemistry and Biochemistry
University of Maryland, College Park 20742
efrain@umd.edu

Modern data storage utilizes the ability of materials to retain memory. This interesting phenomenon whereby a material 'remembers' is known as hysteresis, and one of the most utilized classes of materials to exhibit such a phenomenon includes ferromagnets. Two other ferroics are well known, ferroelectrics and ferroelastics, but what of the fourth predicted one termed ferrotoroidicity? A common characteristic of ferroic materials is spontaneous symmetry breaking with respect to an order parameter such as magnetization. The ferrotoroidic order is predicted to break both time-reversal and space-inversion symmetry simultaneously below an antiferromagnetic transition temperature, T_N. This type of ordering whereby toroidal moments line up is more difficult to observe than the others, and we use a materials synthesis approached combined with advanced neutron scattering techniques to further develop this field.



There are certain symmetry-constrained requirements for the magnetic point group to exhibit ferrotoroidicty. We have narrowed our search to transition metal phosphates with the olivine type-structure and transition metal silicates with the pyroxene–type structure to fulfill those symmetry constraints. We will present our work on the solid solutions $LiMn_{1-x}MPO_4$ where M = Fe, Co. We utilize neutron scattering along with magnetization properties to understand how structure, *d*-orbital count, and magnetic exchange interactions are controlling ferrotoroidicty. We will also present preliminary results on the $CaMSi_2O_6$ system for M = Mn, Fe, Co, and Ni. Since ferrotoroidic materials are magnetoelectrics with off-diagonal terms in the linear magnetoelectric tensor, we have started to investigate the role of spherical neutron polarimetry (SNP) to detect ferrotoroidicity. In addition, we will present our efforts to develop SNP in North America, including some preliminary measurements at the NIST Center for Neutron Research.

References

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