MS26.O02

The roles of chirality and polarity in novel multiferroics: MnSb2O6 and Cu3Nb2O8

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At room temperature Cu3Nb2O8 has a centrosymmetric, triclinic crystal structure. If cooled below 24 K, the copper magnetic moments order with a complex, generalized helicoidal magnetic structure that breaks inversion symmetry, giving rise to ferroelectricity. Unusually, the direction of the induced electric polarization vector with respect to the helicoidal spin rotation cannot be reconciled by conventional theories of magneto-electric coupling. Instead, we show that the observed multiferroic properties of Cu3Nb2O8 may be explained through a phenomenological analysis based upon coupling between the magnetic chirality, electric polarity, and a structural axial rotation. Trigonal MnSb2O6 crystallizes with a chiral crystal structure. Typically, magnetic materials with a chiral crystal lattice order with a chiral magnetic structure, where the magnetic exchange interactions and anisotropies follow the symmetry of the lattice. The magnetism of MnSi is a classic example of this scenario, in which exotic skyrmion phases emerge out of a helical magnetic state. To the contrary, we show that the low temperature magnetic structure of MnSb2O6 is cycloidal, described by a magnetic polarity as opposed to a chirality. We demonstrate through ab-initio calculations that this magnetic structure is in fact the ground state of the symmetric-exchange Heisenberg spin Hamiltonian, which has higher symmetry than the underlying crystal lattice. Furthermore, the phenomenology may be understood by considering the coupling between structural chirality, magnetic polarity, and a magnetic axial rotation. As a result, we predict MnSb2O6 to be multiferroic with a weak ferroelectric polarization.

Keywords: Multiferroics, Magnetism, Ferroelectricity