Multiferroics and skyrmions as derived from helimagnets

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The frustration in spin exchange interactions as well as the Dzyaloshinskii-Moriya(DM) interaction on noncentrosymmetric lattice can often produce the helical spin structure. Among them, the transverse-spiral (cycloidal) structure in an insulating magnet can almost always produce the ferroelectricity whose polarization direction depends on the vector spin chirality. Even for the case of the longitudinal-spiral or proper screw structure, the coupling of such a spin texture to the underlying chemical lattice can produce the ferroelectric polarization via the spin-orbit interaction; this can be widely observed in actual triangular-lattice magnets like delafossites Cu*M*O2 and layered halides *MX*2 (*M*=transition metal element, *X*=halogen). The magnetically flexible spin structure immediately leads to the magnetic control of the ferroelectric polarization vector, both in magnitude and direction.

Another prototype of helimagnetism stems from the DM interaction on the non-centrosymmetric crystal; archetypal examples are the B20 type (FeSi type) transition-metal silicide and germanide families. Recently, the lattice of skyrmions, *i.e.* vortex-like spin-swirling object, was confirmed to form in a narrow temperature(T) -magnetic field(B) region of the helimagnetic phase in bulk. Furthermore, thin films of B20 type *M*Si (*M*=Mn or $Fe_{1-x}Co_x$) or *M*Ge (*M*=Mn, Fe) , whose thickness is smaller than the helical spin modulation period (=10-100nm), ubiquitously form the two-dimensional skyrmion crystal with magnetic fields (B) applied normal to the film plane over a wide T-B region down to the lowest temperature. The implication of such a skyrmion crystal in the magneto-transport properties is discussed, such as the topological Hall effect as induced by scalar spin chirality of skyrmion. Skrymions are also found in multiferroics, in which external electric field will enable the control of skyrmion dynamics.