Colloquium on Solid-State Physics

Department of Physics
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Extended multiferroics for emergent electromagnetic phenomena

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Abstract:
Breaking both time-reversal symmetry and space-inversion symmetry in a solid produces intriguing phenomena and functions arising from electrodynamics under spin-orbit coupling. One such example is the emergence of multiferroics, in particular the magnetically induced ferroelectrics where the chiral spin order is a source of ferroelectrics and hence enables the cross-control of electric polarization and magnetism, i.e., generalized electromagnetic induction. The concept of the electric polarization, being typical of the broken space-inversion symmetry, can be generalized to the case of electron conductors. Quantum materials viewed as the extended multiferroics include magnetic ferroelectric (Rashba) semiconductor, one-surface magnetized topological insulators, magnetic polar (Weyl) semimetals, and magnetic conductors of cycloidal spin order or skyrmion lattice. While the energy dissipation occurs more or less in charge transport process apart from genuine insulating multiferroics, highly energy-effective control of magnetism, such as the current-induced magnetization reversal, is possible in the extended multiferroics. One other important characteristic for the extended multiferroics is nonlinear and nonreciprocal phenomena in charge transport, such as magnetically-switchable diode effect and photovoltaic (injection current) effect.
Here, we overview the extended multiferroic conductors and their emergent electromagnetic induction phenomena.