

Coupling between charge distribution and magnetic textures in a magnetic Weyl semimetal

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In quantum Hall systems, a magnetic field induces a charge-density response governed by the Hall conductivity through the Středa formula [1]. This cross-correlated response also occurs in magnetic Weyl semimetals, where the anomalous Hall conductivity depends on the orientation of the magnetic order. A uniform magnetic field thus induces a nonuniform charge distribution in a magnetic texture. For a domain wall separating domains with opposite orientations of the magnetic order, this charge distribution gives rise to an electric polarization induced by the magnetic field.

We propose a mechanism for stabilizing magnetic domain walls by an electric field through its coupling to this electric polarization. The coupling between the electric polarization and a uniform electric field lowers the free energy of the domain-wall state when the electric field is parallel to the electric polarization. If this energy gain exceeds the domain-wall formation energy, the domain-wall state becomes energetically favorable compared with the state with uniform magnetic order.

To demonstrate this mechanism, we employ a Wilson–Dirac lattice model describing a single pair of Weyl nodes. As a representative case, we use parameters based on the theoretical description of the compensated ferrimagnetic Weyl semimetal Ti_2MnAl [2,3]. Spin compensation suppresses the net spin Zeeman energy favoring uniform magnetic order, allowing orbital effects of the magnetic field to play a central role [3]. We show that this mechanism lowers the electronic free energy of the domain-wall state below that of the state with uniform magnetic order. This mechanism provides electrical control of magnetic textures in a uniform magnetic field.

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