Topological Vortex Domains in Quantum Materials

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Engineering of domains and domain boundaries is quintessential for technological exploitation of numerous functional materials. However, it has only recently realized that the configuration of these domains/domain boundaries can have non-trivial topology. We will discuss a new topological classification scheme of domain/domain boundary configurations with two-dimensional order parameters: $Z_m \times Z_n$ domains (m directional variants and n translational antiphases) and Z_l vortices (where l number of domains and that of domain boundaries merge). This classification, with the concept of topological protection and topological charge conservation, has been applied to a wide range of materials such as improper ferroelectric $R(Mn,Fe)O_3$, antipolar $In(Mn,Ga)O_3$, hybrid improper ferroelectric $(Ca,Sr)_3Ti_2O_7$, chiral (and ferromagnetic) $Fe_{1/3}TaS_2$, and magnetic (and superconducting) Sr_2VO_3FeAs. We will also discuss the emergent physical properties of domain boundaries, distinct from those of domains. The presented topological consideration provides a basis in understanding the formation, kinetics, manipulation and property optimization of domains/domain boundaries in quantum materials.