# Preface

Topological defects play important roles in nature. They are found in fields as diverse as cosmology, particle physics, superfluidity, liquid crystals, and metallurgy, manifesting themselves as screw/edge dislocations in liquid crystals, magnetic flux tubes in superconductors, and vortices in superfluids, for example. They can also be found in ferroic materials, i.e., materials with a spontaneous reversible ordering, such as magnetic materials, ferroelectrics, and ferroelastic materials, which have been studied for a long time and are used widely in sensors, actuators, information technology, and other smart materials applications. Ferroic phases can arise in more than one distinct orientation of the order parameter, thus spatial variations in the orientations of the order parameter are accommodated through the formation of discrete domain structures. Adjacent domains are separated by naturally occurring planar topological defects called domain walls. Over the last few years they have been intensively investigated with respect to their inherent functional behavior in various studies involving ceramics, thin films, and single crystalline material. The fact that the electronic conductivity of domain walls in ferroelectrics and multiferroics can be utilized for nanoscale functional elements and new concepts involving magnetic domain walls for memory and spintronic applications have sparked wide interest and have led to the finding of unique properties associated with such topological structures. The understanding of these phenomena has progressed to a point where we can say that the physical properties of topological structures such as domain walls can be completely different from those of the parent bulk material phase.

Although domain walls are the commonly understood concept of ferroic order, they are not the only way in which spatially varying order parameters can be arranged. Alternatively, more complex patterns can develop in which the order parameter changes in different ways as described, e.g., by the topological theory of defects in ordered media by N.D. Mermin. When combined with local defects or singularities, the number of possible geometrical patterns and textures that arise can be manifold and include vortex structures and skyrmions. Which kind of ferroic micro- or nanostructure developments depends critically on the relative magnitudes of various energies associated with exchange, spin–orbit interaction, crystallographic anisotropy, and surfaces and interfaces in ferroic materials. Physical dimensions of the specific material and its morphology are also important in determining the exact nature of the ferroic patterns that develop in equilibrium, which include flux-closure structures and other complex topological patterns such as periodic arrays of magnetic skyrmions that can be observed, e.g., by magnetic force microscopy.

It is only within the last few years that experiments have focused on trying to find and study such topological structures in ferroic materials. It is clear today that these interesting structures can form in ferroelectrics and magnetic systems; however, the study of their basic properties and the exploration of their potential for future applications has only just begun. This book is an effort to capture some of the interesting developments in this rapidly changing field of research. Tuning, manipulating, and exploiting the physical properties of such topological structures provides a new playground for condensed matter and functional materials research. In addition, it offers a novel platform for future nanotechnology.

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