Chapter 5
Multiferroic Magnetoelectric Materials, Mechanism, Classification, and Applications

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ABSTRACT

Materials science and solid-state physics have significantly influenced economic growth and development, leading to the development of computer technologies, wireless communications, and consumer electronics. Emerging fields like nanomaterials, graphene, carbon nanotubes, smart functional materials, spintronic materials, biomaterials, and multiferroic materials have the potential to create new technological breakthroughs and economic impact. These multifunctional solid-state compounds address diverse and multidisciplinary technologies, with multiferroic technologies expected to be valued at billions of dollars in the future.

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1. INTRODUCTION

H. Schmid first used the term "multiferroic" in 1994, which is a rather late date. It describes materials that simultaneously exhibit (anti)ferromagnetism, ferroelectricity, and ferro elasticity, or two or more distinct ferroic orders. Materials with couplings between several ordering types, such as elastic, charge, and magnetic, where ferroelectricity and magnetism are strongly related, are known as multiferroics. An important question that can be further developed is whether Different ferroic states can coexist in a single-phase material using symmetry arguments and Landau theory for continuous phase transitions. This demonstrates how the spin structure can break spatial inversion symmetry alone, resulting in ferroelectric order. For a material to be classified as multiferroic, it must possess at least two primary ferroic qualities in a single phase, and there may even be a coupling between them. That indicates that a material need not couple with them to be multiferroic.

Ferroelectricity is induced at low temperatures in those multiferroic substances by complicated spin order that results from frustrated and competing interactions. Magnetoelectric coupling is the connection between long-range magnetic and ferroelectric order, i.e., in which magnetic polarization with electric field and electric polarization with magnetic field are switchable. Because of their magnetoelectric coupling, these materials belong to a special class of multiferroic materials. Materials with innovative electronic properties can be designed thanks to the magnetoelectric interaction. In addition to the cross-coupling responses of magnetization and polarization (i.e., the introduction of a magnetic field H that causes electric polarization P to emerge, or magnetization M in an electric field E), the concept of multiferroicity also introduces an intriguing twist to the field of multiferroics: systems in which two types of ordering—ferroelectricity (spontaneous polarization) and (Ferro)magnetism (spontaneous magnetization)—can exist simultaneously in a single substance without the presence of outside magnetic and electric forces Fig. 1.

2. TYPES OF MULTIFERROIC MATERIALS

The most crucial factors in classifying multiferroic materials are the method of origin of the ferrous features and how they are coupled. The two forms of multiferroic materials are distinguished by the source of their ferroelectricity and magnetism: Division I and Division II.

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