Available online at www.sciencedirect.com
SciVerse ScienceDirect
Acta Materialia 60 (2012) 2449–2470
Acta MATERIALIA
www.elsevier.com/locate/actamat

Overview No. 151

Multiferroic and magnetoelectric heterostructures

L.W. Martin [a,*], R. Ramesh [b]

[a] Department of Materials Science and Engineering and F. Seitz Materials Research Laboratory, University of Illinois, Urbana-Champaign, Urbana, IL 61801, USA
[b] Department of Materials Science and Engineering and Department of Physics, Lawrence Berkeley National Laboratory, University of California, Berkeley, CA 94720, USA

Available online 25 January 2012

Abstract

We review recent developments and advances in multiferroic and magnetoelectric heterostructures. Driven by the promise of new materials functionality (i.e. electric field control of ferromagnetism), extensive on-going research is focused on the search for and characterization of new multiferroic materials. In this review we develop a comprehensive overview of multiferroic materials, including details on the nature of order parameters and coupling in these materials, the scarcity of such materials in single phase form, routes to create and control the properties of these materials, and we finish by investigating such effects in a number of model materials and heterostructures. This includes an in-depth discussion of $BiFeO_3$, an investigation of recent advances in magnetoelectric materials, and an introduction to a variety of approaches by which one can achieve novel materials functionality.

Keywords: Multtiferroics; Magnetoelectrics; $BiFeO_3$; Oxide thin films

1. Introduction

Complex oxides represent a broad class of materials that have a wide range of crystal structures and functionalities. Among them, the study of magnetic, ferroelectric, and more recently, multiferroic properties has stimulated considerable interest. The study of multiferroic and magnetoelectric materials, in particular, has experienced a dramatic increase in research effort over the past decade and today we see the emergence of real-life applications based on these efforts. This work has been driven, in part, by the development of new thin film growth techniques and the resulting access to high-quality materials for further study. In general, the field of functional oxide materials has experienced unprecedented growth during the past decades in terms of the discovery of new materials systems and physical phenomena, advances in characterization, and development of deeper understanding of the fundamental properties and how to control these properties through systematic changes in crystal chemistry (i.e. doping or alloying), strain, and other variables. Perhaps the most interesting recent manifestation of the complex and rich diversity of physical phenomena is the emergence of coupled behavior, in which the lattice, orbital, spin, and charge degrees of freedom are coupled through either quantum mechanics or through engineering design of artificial heterostructures. Of course, such coupling between phenomena is not necessarily new. Piezoelectrics exhibit coupling between mechanics and electrical degrees of freedom and ferromagnetic shape memory alloys exhibit coupling between magnetism and mechanics. But in the last decade, renewed interest in the potential of coupling between the spin and charge degrees of freedom has fascinated researchers and engineers not only from a fundamental perspective, but from an applied direction as well. Imagine a world in which one can control and manipulate magnetism with electric fields (which are intrinsically much easier to use in an actual device, especially in small dimensions, and can potentially provide routes to lower power/energy consumption in systems), thus eliminating currents and magnetic fields.

* Corresponding author.
E-mail address: lwmartin@illinois.edu (L.W. Martin).

1359-6454/$36.00
doi:10.1016/j.actamat.2011.12.024