SYMM 2 Multiferroic Materials - Experiment

Time: Tuesday 16:15–18:15 Room: HSZ 04

Invited Talk

SYMM 2.1 Tue 16:15 HSZ 04

Multifunctional Complex Oxide Heterostructures — •R. Ramesh — Department of Materials Science and Engineering, and Department of Physics, University of California, Berkeley, CA 94720

Complex perovskite oxides exhibit a rich spectrum of functional responses, including magnetism, ferroelectricity, highly correlated electron behavior, superconductivity, etc. There exists a small set of materials which exhibit multiple order parameters; these are known as multiferroics. Using our work in the field of ferroelectrics and ferromagnetics as the background, we are now exploring such materials, as epitaxial thin films as well as nanostructures. Specifically, we are studying the role of thin film growth, heteroepitaxy and processing on the basic properties as well as magnitude of the coupling between the order parameters. In single phase multiferroic perovskites, such as $BiFeO_3$, we have found significant enhancements in magnetism and ferroelectricity compared to bulk. Detailed measurements indicate that the enhancement in magnetism is due to a mixed Fe^{2+}/Fe^{3+} state in the films, while the ferroelectric polarization is reasonably commensurate with that predicted from first principles theory. A very exciting new development has been the discovery of the formation of spontaneously assembled nanostructures consisting of a ferromagnetic phase embedded in a ferroelectric matrix that exhibit very strong coupling between the two order parameters. This involves 3-dimensional heteroepitaxy between the substrate, the matrix perovskite phase and spinel phase that is embedded as single crystalline pillars in this matrix. This epitaxial coupling is critical and is responsible for the significantly higher magnetoelectric coupling and magnetic anisotropy in such vertical heterostructures compared to a conventional heterostructure.

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Invited Talk

SYMM 2.2 Tue 16:45 HSZ 04

Some Observations about Static Scaling: Domain Widths and Circular and Toroidal Ordering in Ferroelectrics, Ferromagnets, and Magnetoelectrics — •J. Scott — Cambridge University, Cambridge, UK

In 1946 Charles Kittel derived a formula for the width w of 180-degree domains, varying as the square root of the sample thickness d, and in the same early paper showed that nano-structures (nano-wires and nano-dots) would have circular ordering of spins. Both ideas were later independently rediscovered, w being proportional to the square root of d by Mitsui and Furuichi (Phys. Rev. 1953), and circular or toroidal ordering in ferroelectrics by Ginzburg in 1981-1984. Very recently the latter idea was put on an atomistic ab initio level by Naumov et al. (Nature 2004). In this talk I combine Kittel's equation with a less well known one of Zhirnov (1959), which shows that the domain wall thicknesses D also varies as the square root of d. The resulting formula is (w-squared)/Dd = G, where G is a dimensionless constant = 32 in barium titanate and 1 in Rochelle Salt. This formula fits barium titanate over six decades of thickness d, from 1.5 nm to 1.5 mm (figure below). Where this formula breaks down depends upon boundary conditions and size, which connects it to circular/toroidal ordering. Moreover, as Ginzburg first showed, the symmetry requirements for toroidal ordering are closely related to those for magnetoelectricity (Schmid, 1994).

Invited Talk

SYMM 2.3 Tue 17:15 HSZ 04

Magnetoelectric Effect and Toroidal Ordering in Multiferroic Manganites — •M. Fiebig[1], Th. Lottermoser[1], and Th. Lonkai[2] — [1]Max-Born-Institut, Max-Born-Strasse 2A, 12489 Berlin, Germany — [2]Institut für Angewandte Physik, Universität Tübingen, 72076 Tübingen, Germany; and Hahn-Meitner-Institut, Glienicker Strasse 100, 14109 Berlin, Germany

Recently, an enormous interest in multiferroic compounds which unite two or more different forms of primary ferroic ordering in one phase is observed. Aside from technological aspects the interplay of different forms of (anti-) ferroic ordering is a rich source for exploring the fundamental science of phase control. I will discuss the coexistence of magnetic and electrical ordering in the hexagonal rare-earth manganites $RMnO_3$ (R=Ho,Yb). With ferroelectricity and magnetic Mn^{3+} and R^{3+} ordering the compounds possess 4 ordered sublattices. I will show how microscopic magnetoelectric correlations between sublattices in combination with multiple frustration lead to giant manifestations of macroscopic magnetoelectric behavior. This leads to magnetic phase control by external electric or magnetic fields or temperature. Furthermore, I will argue that in addition to ferromagnetism, ferroelectricity, and ferroelasticity as the three widely known forms of primary ferroic ordering, ferrotoroidicity formation of a spontaneous magnetic vortex must be included as the fourth variety. Toroidic domains can exist and have already been observed in multiferroic $YMnO_3$, but were not recognized as such. However, after introducing toroidic domains as physically independent states the former observation becomes physically sound.

Invited Talk

SYMM 2.4 Tue 17:45 HSZ 04

Magnetoelectric Effects in Multiferroics — •A. Loidl, J. Hemberger, A. Pimenov, P. Lunkenheimer, A. A. Mukhin, and V. Tsurkan — Center for Electronic Correlations and Magnetism, University of Augsburg, Germany

Magnetoelectric phenomena were investigated for two different multiferroic systems. The coupling of dielectric and magnetic properties and the simultaneous occurrence of long-range magnetic and polar order are discussed for manganites and spinels. A phase diagram of $Eu_{1-x}Gd_xMnO_3$ as function of temperature and magnetic field is established. It resembles the main features of the well-known magneto-electric phase diagram of $RMnO_3$ (R = rare earth) with a sequence of magnetic and polar phase transitions for varying ionic radii of the rare earth ions. Special attention is paid to the occurrence of electromagnons, i.e. spin waves that can only be excited by an ac electric field. These excitations also allow tuning the index of refraction by moderate magnetic fields. In the second part we discuss the simultaneous appearance of colossal magneto-resistance and colossal magneto-capacitance effects in chromium sulfo spinels. Ferroelectricity appears well above the onset of ferromagnetism in $CdCr_2S_4$ and above a complex antiferromagnetic order in $HgCr_2S_4$. We speculate that the occurrence of ferroelectricity in these multiferroic compounds is rather of electronic than of ionic origin.