Multiferroic Materials

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Abstract

Primary ferroic properties found in solids include ferromagnetism, ferroelectricity, ferroelasticity and ferrotoroidicity. Apart from the last, these properties are extremely important for our daily life: they are exploited in transformers, magnetic data storage, in position sensors, actuators, micromechanical applications and so on. In the sixties of the last century, research started to explore the requirements for a joined appearance of more than one ferroic property [1, 2 and reviews 3-7] and termed such materials „multiferroic“.

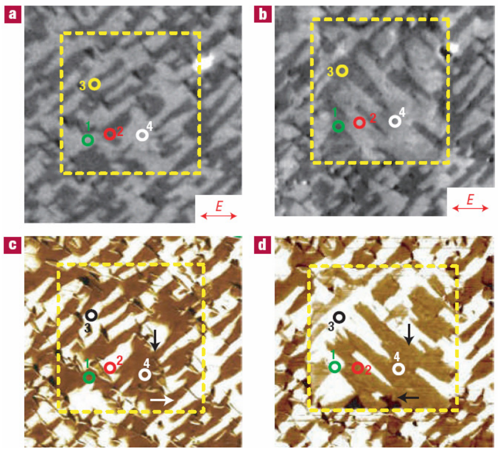

Fig.1: Coupled switching of antiferromagnetic (upper panel) and ferroelectric (lower panel) domains in $BiFeO_3$ at ambient temperature. (T. Zhao et al., Nat. Materials 2006)

Multiferroics with coupled ferroic properties, sufficiently large polarization and appropriate working temperatures would widely enhance the choices to sense and control. One example is the manipulation of the magnetization by an electric field utilizing the magnetoelectric effect. In this lecture, the focus is on magnetic and ferroelectric multiferroics. Early investigated materials like Cr2O3 showed an extremely small effect. Modern methods of preparation (thin film and nanostructuring techniques), investigation (scattering techniques, non-linear optics and further) and theoretical modelling have opened ways toward discovery and design of strongly magnetoelectric materials. This has triggered a revival of research activities [3-7]. Current efforts are devoted to areas including the following: (i) discovery of new single-phase compounds (spin spirals and charge ordering as source of electric polarization), (ii) experimental detection of the coupling phenomena (e. g., of the different ferroic domains) and (iii) design of nanocomposites of magnetic and ferroelectric components (mostly in thin film structures [4 6, 8-10]). Whereas room-temperature single-phase multiferroics are very few (BiFeO3), composites promise a potential for application and substantial magnetoelectric responses have been reported [5,6,8]. However, there is a way to go, since thin film fabriaction has started few years ago and very little is known about dynamic properties of multiferroics.

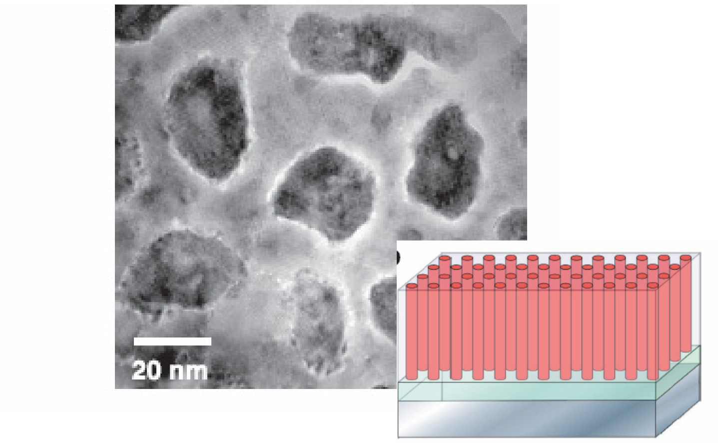

Fig.2: Self-organized growth of epitaxial $BaTiO_3$- $CoFe_2O_4$ nanocolumnar structures in films grown by pulsed laser deposition (H. Zheng et al., Science 303, 661 (2004))

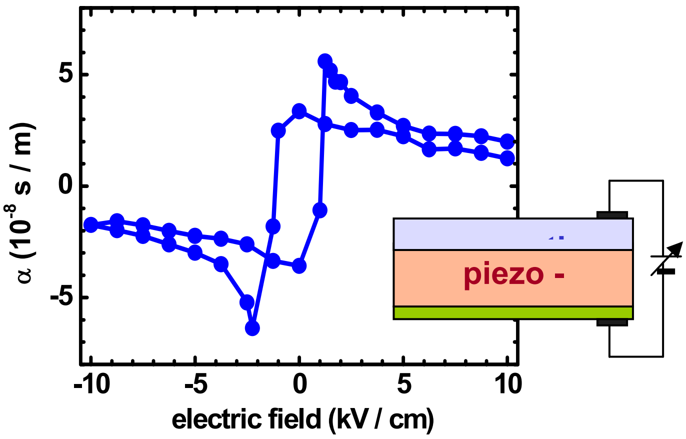

Fig.3: Magnetoelectric coupling coefficient a = m0 dM/dE at 300 K with the magnetization M controlled by applied electric field E in an epitaxially grown $La_{0.7}Sr_{0.3}MnO_3$ film on PMN-PT(001) (Ref.8)

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