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Giant Magnetoelectric Effect in Hexagonal Multiferroic Manganites

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Recently an enormous interest in magnetoelectric (ME) phenomena is observed because composite materials and multiferroics exhibit structural and giant ME effects that exceed previous effects by orders of magnitude and control phase transitions. I will discuss 3 manifestations of giant ME coupling in ferroelectric (FEL) antiferromagnetic (AFM) $RMnO_3$ (R = Sc, Y, In, Ho-Lu). (i) External magnetic or electric fields induce ferromagnetic R^{3+} ordering which is reversibly switched on or off. The process is monitored by magneto-optical techniques (second harmonic generation, Faraday rotation). Its microscopy is disclosed by neutron and x-ray powder diffraction. The ME phase control is driven by an asymmetry in the R^{3+}-Mn^{3+} superexchange which originates in the ferroelectric distortion and lowers the free energy. [Nature **430**, 541 (2004)] (ii) Interaction of FEL and AFM domain walls which clamps the AFM to the FEL domains. The coupling is revealed by simultaneous imaging of FEL, AFM, and ME 180° domains by second harmonic generation. It roots in a piezomagnetic interaction between the magnetization of the AFM walls and strain in the FEL walls which lowers the free energy. [Nature **419**, 818 (2002)] (iii) Massive formation of *spin-rotation domains* which supplement *spin-reversal domains* in the course of a Mn^{3+} spin reorientation. This leads to a local ME effect that is only allowed because of the low symmetry of the domain walls. [Phys. Rev. B, (2005)] From our results basic requirements for other candidate materials to exhibit magnetoelectric phase control are identified.