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Direct visualization of magnetoelectric domains in hexagonal manganites[1]

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Multiferroics are materials with coexisting magnetic and ferroelectric orders, where the cross-coupling between two ferroic orders can result in strong magnetoelectric effects [1-4]. Therefore, it is of both fundamental and technological interest to visualize cross-coupled magnetoelectric domains and domain walls in multiferroics. Recently, intriguing topological defects with six interlocked structural antiphase and ferroelectric domains merging into a vortex core were revealed in multiferroic hexagonal $RE\mathrm{MnO_3}$ (RE=rare earths) [5, 6]. Many emergent phenomena, such as enhanced conduction and unusual piezoelectric response, were observed in charged ferroelectric domain walls protected by these topological defects [7-9]. More interestingly, alternating uncompensated magnetic moments were discovered at coupled structural antiphase and ferroelectric domain walls in hexagonal manganites using cryogenic magnetic force microscopy (MFM) [10], which demonstrates the cross-coupling between ferroelectric and magnetic orders. Using a newly-developed Magnetoelectric Force Microscopy (MeFM), which combines MFM with in-situ modulating high electric fields, we directly visualize the magnetoelectric response of the multiferroic domains in hexagonal manganites. The development of MeFM opens up explorations of emergent phenomena in multifunctional materials with multiple coupled orders [11, 12].

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