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Multiferroic vortices in hexagonal manganites[1]

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Hexagonal rare earth manganites (REMnO$_3$) show a unique improper ferroelectricity induced by structural trimerization. Extensive research on these systems has been carried out due to its potential application in memory and the intriguing multiferroicity (coexistence of ferroelectricity and antiferromagnetism). However, the true relationship between ferroelectric domains and structural domains has never been revealed. Using transmission electron microscopy (TEM) and conductive atomic force microscopy (cAFM), we observed an intriguing conductive "cloverleaf" pattern of six domains emerging from one point, all distinctly characterized by polarization orientation and structural antiphase relationships in hexagonal manganites.[2] The nanoscale electric conduction between a sharp tip and the surface is intrinsically modulated by the ferroelectric polarization.[3] The cloverleaf defects are structural vortices where the phase angle goes successively through all six phases.[4] In addition, we discovered that the ferroelectric domain walls and structural antiphase boundaries are mutually locked. Correlated with previous observation of coupled ferroelectric and antiferromagnetic domain walls,[5] our results suggest that these cloverleaf defects are indeed multiferroic vortices. These fascinating results reveal the rich physics of the hexagonal system with a semiconducting bandgap where structural trimerization, ferroelectricity, magnetism and charge conduction are intricately coupled.

[1]NSF-DMR-0844807

[2]T. Choi, et al, "Insulating interlocked ferroelectric and structural antiphase domain walls in multiferroic YMnO$_3$" Nature Materials, **9**, 253-258 (2010).

[3]W. Wu, et al, "Polarization-Modulated Rectification at Ferroelectric Surfaces" Phys. Rev. Lett., **104**, 217601 (2010).

[4]M. Mostovoy, "a whirlwind of opportunities," Nature Materials, **9**, 188-190 (2010).

[5]M. Fiebig, et al, "Observation of coupled magnetic and electric domains," Nature, **419**, 818 (2002).