MULTIFERROIC VORTICES IN HEXAGONAL $YMnO_3$

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Hexagonal $REMnO_3$ (RE= rare earths) with RE=Ho-Lu, Y, and Sc, is an improper ferroelectric where the size mismatch between RE and Mn induces a trimerization-type structural phase transition, and this structural transition leads to ferroelectricity. For the last two decades, ferroelectric $REMnO_3$ has been extensively studied as a candidate material for ferroelectric memories and also for its multiferroicity – the coexisting nature of ferroelectricity and magnetism. Despite this research the true ferroelectric domain structure and its relationship with structural domains have never been revealed. Using transmission electron microscopy and conductive atomic force microscopy, we have investigated the relationship among trimerization antiphase domains, ferroelectric domains and antiferromagnetic domains in $REMnO_3$. We found that ferroelectric domain walls and structural antiphase boundaries are mutually interlocked. In addition, we discovered a vortex structure with six domains emerging from one point - all distinctly characterized by polarization orientation, structural antiphase, and antiferromagnetic relationships. This vortex can be considered as a topological defect in a multiferroic. We also found that ferroelectric domains and walls have distinct electronic transport properties. These fascinating results reveal the rich physics of the hexagonal system with a truly-semiconducting band gap where structural trimerization, ferroelectricity, magnetism, and charge conduction are intricately coupled.