MAR12-2011-000766

Abstract for an Invited Paper
for the MAR12 Meeting of
the American Physical Society

Multiferroic vortices: arrested Kosterlitz-Thouless order[1]

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The fascinating concept of topological defects permeates ubiquitously our understanding of the early-stage universe, hurricanes, quantum matters such as superfluids and superconductors, and also technological materials such as liquid crystals and magnets. Large-scale spatial configurations of these topological defects have been investigated only in a limited degree. Exceptions include the cases of supercurrent vortices or liquid crystals, but they tend to exhibit either trivial or rather-irregular configurations. 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 three structural domains, each of which can support two directions of ferroelectric polarization. We reported that domains in h-$REMnO_3$ meet in cloverleaf arrangements that cycle through all six domain configurations, Occurring in pairs, the cloverleafs can be viewed as vortices and antivortices, in which the cycle of domain configurations is reversed. Vortices and antivortices are topological defects: even in a strong electric field they won't annihilate. These ferroelectric vortices/antivortices are found to be associated with intriguing magnetism. The seemingly-irregular configurations of a zoo of multiferroic vortices and antivortices in h-$REMnO_3$ can be neatly analyzed in terms of graph theory and this graph theoretical analysis reflects the nature of self-organized criticality in complexity phenomena as well as the condensation and eventual annihilation processes of topological vortex-antivortex pairs. Furthermore, these numerous multiferroic vortices/antivortices can be understood as an arrested Kosterlitz-Thouless phase.

[1] Insulating Interlocked Ferroelectric and Structural Antiphase Domain Walls in Multiferroic $YMnO_3$, T. Choi, - - -, S-W. Cheong, Nature Materials 9, 253 (2010).
[2] Self-organization, condensation, and annihilation of topological vortices and antivortices in a multiferroic, S. C. Chae, - - - S.-W. Cheong, PNAS 107, 21366 (2010).
[3] Direct observation of the proliferation of ferroelectric dislocation loops and vortex-antivortex pairs, S. C. Chae, - - -, S.-W. Cheong, Phys. Rev. Lett., submitted.

[1]This work is supported by NSF grant DMR-1104484 and DOE grant DE-FG02-07ER46382.