Striping of orbital-order with charge-disorder in optimally doped manganites

Mark Senn

University of Warwick, Coventry, United Kingdom;

m.senn@warwick.ac.uk

A central line of inquiry in condensed matter science has been to understand how the competition between different states of matter give rise to emergent physical properties. Perhaps some of the most studied systems in this respect are the hole-doped LaMnO3 perovskites, with interest in the past three decades being stimulated on account of their colossal magnetoresistance (CMR). However, phase segregation between ferromagnetic (FM) metallic and antiferromagnetic (AFM) insulating states, which itself is believed to be responsible for the colossal change in resistance under applied magnetic field, has until now prevented a full atomistic level understanding of the orbital ordered (OO) state at the optimally doped level. Here, through the detailed crystallographic analysis of the hole-doped phase diagram of a prototype system, we show that the superposition of two distinct lattice modes gives rise to a striped structure of OO Jahn-Teller active Mn3+ and charge disordered (CD) Mn3.5+ layers in a 1:3 ratio. This superposition leads to a cancellation of the Jahn-Teller-like oxygen atom displacements in the CD layers only at the 3/8th doping level, coincident with the maximum CMR response of the manganties. Furthermore, the periodic striping of layers containing Mn3.5+, separated by layers of fully ordered Mn3+, provides a natural mechanism though which long range OO can melt, a prerequisite for the emergence of the FM conducting state. The competition between insulating and conducting states is seen to be a key feature in understanding the properties in highly correlated electron systems, many of which, such as the CMR and high temperature superconductivity, only emerge at or near specific doping values.

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