

Creating an Antiferromagnetic Metal in $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ by Digital Synthesis

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The perovskite manganite $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ has a rich structural and magnetic phase diagram, exhibiting ferromagnetism (F) for La-rich compositions and antiferromagnetism (AF) for those that are Sr-rich. Our interest lies in the region near the $x=0.5$ doping level containing the F-AF phase transition, particularly the role of disorder in nucleating the F or AF state. We have digitally synthesized fully-epitaxial superlattices of LaMnO_3 and SrMnO_3 , designed to be equivalent in composition to random alloys of $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ in the vicinity of $x=0.5$. In our digital synthesis method, whereby we prepare a superlattice by interleaving an integer number of undoped LaMnO_3 and SrMnO_3 layers, we have eliminated disorder at the La/Sr site, allowing us to address the effect of order on the F-AF phase transition. We have achieved atomic layer precision in the synthesis of these superlattices, as confirmed by structural characterization. For $x>0.5$, A-type antiferromagnetic order (F alignment within the plane, AF alignment of neighboring planes) is verified by neutron diffraction, where the $(0\ 0\ \frac{1}{2})$ diffraction peak emerges for temperatures below the Neel temperature. Moreover, the Neel temperature for this ordered structure is enhanced over that of the random alloy. Remarkably, rather than the insulating behavior typically seen for Sr-rich, AF compositions, these superlattices have a relatively lower resistivity (<4 mohm-cm). With such metal-like behavior in an A-type antiferromagnet, one could envision using the discrete layers of opposite spins to transport purely spin currents with long spin coherence lengths, or to propagate Cooper pairs by means of a proximity effect with a superconductor.