Interface Effects in Perovskite Superlattices

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The effect of interface disorder in perovskite superlattices, either with the substrate or between layers dominates the physics of the material, even when the lattice parameter of the component materials differs in less than 1%. Unexpected behavior emerges, like exchange bias in a system where no antiferromagnetic material has been included in the superlattice design.

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When a superlattice is grown, disorder at the interfaces plays an important role in determining the physical properties of the artificially engineered material.1 This disorder, which can take the form of interdiffusion, step disorder, strains, etc. affects the properties either by modifying the interaction between the materials or by modifying the interface material through alloying.

The perovskite High-\(T_C\) superconductors and colossal magnetoresistive manganites are interesting partners for the construction of a superlattice. Not only magnetic and superconducting materials are put in contact, but the structures are reasonably similar, which will produce good interface crystalline matching and reduce the effects of interface scattering.

In this work we describe some magnetic and transport properties of \(YBa_2Cu_3O_{7-\delta}/La_2Ca_1MnO_3\), \(YBCO/LCMO\), and \(La_{0.55}Sr_{0.45}MnO_3/SrTiO_3\), \(LSMO/STO\), superlattices. The samples were grown by dc-sputtering \(^2,3\) on (100)\(MgO\), which lattice parameter (0.421 nm) is 9% larger than the lattice parameter of either component material. All superlattices show strongly textured growth along the (001) direction.

The magnetic properties of the \(YBCO/LCMO\) superlattices show quite unexpected behavior. The inset in figure 1 shows the hysteresis loop found

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Fig. 1. Temperature dependence of the Exchange Bias field, $H_{EB}$, for an $YBa_2Cu_3O_{7-\delta}/La_{2/3}Ca_{1/3}MnO_3$ (3u.c./15u.c.), full circles, and an $YBa_2Cu_3O_{7-\delta}/La_{2/3}Ca_{1/3}MnO_3$ (3u.c./30u.c.), open circles, superlattice. Lines are linear fits to the data. Inset shows the 1 T field cooled hysteresis loop at 5K for the first superlattice, showing the $H_{EB}$ field shift signaling exchange bias. Lines are guides to the eye.

when field cooling in 1 T the superlattice from room temperature. The field shift signaling the existence of exchange bias$^4$ due to a ferromagnetic/antiferromagnetic, $F/AF$, interface, is evident, although no $AF$ material has been included in the superlattice design. Previously,$^6$ we determined through fitting of the X-ray diffraction pattern, the existence of intergrowth of both materials at the interface and layer thickness fluctuation of about 1 unit cell, u.c., of the High-$T_c$ material. This disorder is seemingly generating a layer of $AF$ manganite by changing the $Mn$ valence towards 4+ either through oxygen stoichiometry, crystalline environment change, i.e. stress, or cation interdiffusion. This result indicates the origin of the very low saturation magnetization, $M_s$, values measured here and in samples grown on (100)$STO$, when compared to the nominal values expected from the $LCMO$ layer thickness.$^2$

This field shift, $H_{EB}$, depends on temperature with an exponential