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Charge, Orbital, and Spin Ordering in CMR Films Controlled by Crystal Symmetry and Lattice Strains

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A hole-doped perovskite manganite $La_{1-x}M_xMnO_3$ ($M = Ca, Sr$) belongs to the strongly correlated systems, which can be treated as intrinsically inhomogeneous owing to a strong tendency toward phase separation, typically involving the ferromagnetic metallic and the antiferromagnetic charge- and orbital-ordered insulating (COI) domains. On the other hand, a strong effect of the lattice strain on the charge, the spin and the orbital states in epitaxially-grown CMR films lets us suggest that the crystal structure plays a key role in these processes.

The as-grown $La_{0.8}Ca_{0.2}MnO_3$ films, prepared by rf magnetron sputtering and a two-step cooling of chamber exposed at 400℃ for 1 h, exhibit a highly oriented crystal structure, a sharp anhysteretic metal-insulator transition (MIT) in zero magnetic field at a temperature near 220 K, which is coincident with the Curie point, and a temperature coefficient of resistance of 900%. The MIT testifies features that are typical for a second-kind phase transition, and can be described by the double-exchange Zener model. However, a half-year aging at room temperature in air leads to a separation of the film into two crystalline phases of the cubic and rhombohedral symmetries with different oxygen contents. Both *crystalline* phases present two different electronic and magnetic transitions with similar maximum values of magnetoresistance.

Investigations of the magnetic and the transport properties for $La_{0.7}Ca_{0.3}MnO_{3-\delta}$ films with an oxygen deficiency ($\delta \approx 0.1$) show that the COI state is observed for the film with a thickness d 30 nm, which manifests mainly a cubic crystal structure with an anomalously small lattice parameter for this composition. An increase in the film thickness leads to a structural transition from the lattice-strained cubic to the relaxed rhombohedral phase that is accompanied by a shift of the Curie point to a lower temperature, and to a frustration of the COI state.

The origin of the COI state was observed in a nano-scale twinned $La_{0.65}Ca_{0.35}MnO_3$ film. It is shown that the thermocycling leads to formation of the nonequilibrium state in the ensemble of the charge-ordered domains, and to appearance of a giant switching in resistance up to 100%.

Effects of the lattice strain on the magnetic and the transport properties of $La_{0.8}Sr_{0.2}MnO_3$ films grown on a $LaAlO_3$ (001) substrate and on a $La_{0.8}Ca_{0.2}MnO_3$ layer have also been studied. It was observed that the metal-insulator and the ferromagnetic transitions turn out to be at higher temperatures for the film deposited on $La_{0.8}Ca_{0.2}MnO_3$ layer, with respect to $LaAlO_3$. The dependence of Curie temperature on the bulk and the Jahn-Teller strains has been determined.

Therefore, the *crystalline* phase separation can be a main driving power for formation of the electronic and the magnetic inhomogeneity in the CMR films.