Magnetoresistance of the $\text{La}_{0.7}\text{Ca}_{0.3}\text{MnO}_3$ Single Crystal

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Abstract—The dependence of the resistance $\rho$ of the $\text{La}_{0.7}\text{Ca}_{0.3}\text{MnO}_3$ single crystal on the temperature (in a range of $77 < T < 410$ K) and magnetic field $H$ is studied. The dependence of the magnetoresistance $\Delta\rho/\rho$ of the ferromagnetic phase on the field is shown to be determined by the competition of two mechanisms. In low magnetic fields, the magnetoresistance is positive $\Delta\rho/\rho > 0$ and is determined by changes in the resistance with changing magnetization orientation with respect to the crystallographic axes; in high magnetic fields, the magnetoresistance is negative $\Delta\rho/\rho < 0$, since it is the suppression of spin fluctuations in the magnetic field that plays the principal role. The phase transition from the ferromagnetic to paramagnetic state is a first-order transition close to the second-order one. In the transition range, the magnetoresistance is determined by the resistivity in the zero field $\rho(T)$ and by the shift of the transition temperature $T_C(H)$ in the magnetic field. In the paramagnetic state, the resistivity $\rho(T)$ has an activation character; similarly to the magnetoresistance of other lanthanum manganites, the magnetoresistance of this single crystal is controlled by a change in the activation energy in the magnetic field.

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MAGNETORESISTANCE THE La$_{0.7}$Ca$_{0.3}$MnO$_3$ SINGLE CRYSTAL

Fig. 1. Temperature dependences of the magnetization $M$ and inverse magnetic susceptibility $\chi^{-1} = H/M$ of the La$_{0.7}$Ca$_{0.3}$MnO$_3$ single crystal measured in a field $H = 10$ kOe.

Substantially, namely, below 220 K, between 220 and 250 K, and above 250 K, which correspond to the ferromagnetic metallic phase, magnetic phase transition (with an the extremum $dM(H = 10$ kOe$/dT$ at 235 K), and paramagnetic semiconducting phase, respectively.

Within the region of ferromagnetic ordering (see Fig. 3), in fields below 7 kOe there are dominant processes of domain wall displacement and magnetization rotation; at $H > 10$ kOe, the true magnetization is dominant. The susceptibility $\chi$ of the paraprocess is low ($10^{-4}$ to $10^{-3}$) and, therefore, can be determined only with a significant error (about 30% on average). The inset in Fig. 3 shows the $\chi(T)$ dependence. As the temperature increases, the susceptibility decreases and reaches a minimum at $T = 180$ K; then, it increases abruptly. The increase in $\chi$ with decreasing temperature at $T < 180$ K indicates the presence of nonferromagnetic inclusions in the ferromagnetic matrix. This conclusion agrees with the data of [11], where the authors revealed nonmetallic inclusions in the metallic matrix of La$_{0.7}$Ca$_{0.3}$MnO$_3$ at temperatures substantially below $T_C$.

The resistance of the single crystal under study at $T < 150$ K is described adequately by an expression $\rho(T) = \rho(0) + AT^2$, where $\rho(0) = 0.13$ m$\Omega$ cm and $A = 2.3 \times 10^{-3}$ m$\Omega$ cm/K$^2$ (see the inset (a) in Fig. 2), which is close to the data of [8, 12]. In a temperature range of

Fig. 2. Temperature dependence of the resistivity of the La$_{0.7}$Ca$_{0.3}$MnO$_3$ single crystal. The solid line corresponds to data calculated by Eq. (3) using $E_o = 78$ meV, $\rho_a = 1.7 \times 10^{-3}$ $\Omega$ cm, and $m = 0$. The insets show (a) the dependence of the resistivity on $T^2$ for the ferromagnetic phase and (b) the temperature dependence of the local activation energy for the paramagnetic phase.

Fig. 3. Magnetization curves for the La$_{0.7}$Ca$_{0.3}$MnO$_3$ single crystal in the ferromagnetic region. The inset shows the temperature dependence of the magnetic susceptibility for the paraprocess.