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Influence of Pb-doping on critical parameters in $La_{1-x}Pb_xMnO_3$ perovskites

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Abstract – Critical behavior of polycrystalline $La_{1-x}Pb_xMnO_3$ (x = 0.2 and 0.3) perovskites around T_C has been studied by analyzing the isothermal magnetization data. Based on the modified Arrott plots and critical isothermal analysis, we have determined the critical parameters $\beta = 0.599$, $\gamma = 1.241$, $\delta = 3.07$ and $T_C \approx 291$ K for $La_{0.8}Pb_{0.2}MnO_3$, and $\beta = 0.502$, $\gamma = 1.063$, $\delta = 3.12$ and $T_C \approx 346$ K for $La_{0.7}Pb_{0.3}MnO_3$. It is found that with increasing the Pb concentration, T_C increases from 291 K to 346 K. This is related to the change in the exponent β from 0.599 (for x = 0.1) to a value 0.502 (for x = 0.2) which is close to that of the mean-field model with $\beta = 0.5$.

In recent years, the discovery of colossal magnetoresistance (CMR) in hole-doped perovskite-type manganites $R_{1-x}A_xMnO_3$ (R = La, Pr, Nd and A = Ca, Ca, Ba, Pb, etc.) around the ferromagnetic (FM)-paramagnetic (PM) phase transition temperature (T_C) has attracted intensive interest. Among these compounds, two systems $La_{1-x}Sr_xMnO_3$ and $La_{1-x}Pb_xMnO_3$ show the CMR effect above 300 K when the Sr- and Pb-doping concentration (x) is between 0.1 and 0.4, which are suitable for magnetic applications at room temperature [1,2]. Basically, CMR has been explained basing on theoretical models of double-exchange interaction in addition to polaron effects where changes in the Mn–O bond length and Mn–O–Mn bond angle are taken into account.

To better understand this effect, however, it is necessary to understand the nature of the FM-PM phase transition and magnetic interactions taking place between Mn ions in the manganite host lattice around T_C. One of the effective approaches is the study of the change in the critical exponents β, γ, and δ associated with the spontaneous magnetization $M_s(T,0)$, initial magnetic susceptibility $\chi_0(T)$, and critical isothermal magnetization, respectively [3]. From these critical parameters, we can figure out the type of ferromagnetic interactions, i.e long- or short-range ferromagnetic ordering. In this issue, we present the study of critical behavior of polycrystalline $La_{1-x}Pb_xMnO_3$ (x = 0.2 and 0.3) perovskites prepared by conventional solid-state reaction. Isothermal magnetization measurements were performed on a vibrating sample magnetometer (VSM) with the field range 0 - 1.5 T. The incremental temperature (ΔT) for each M-H curve is 3 - 5 K.

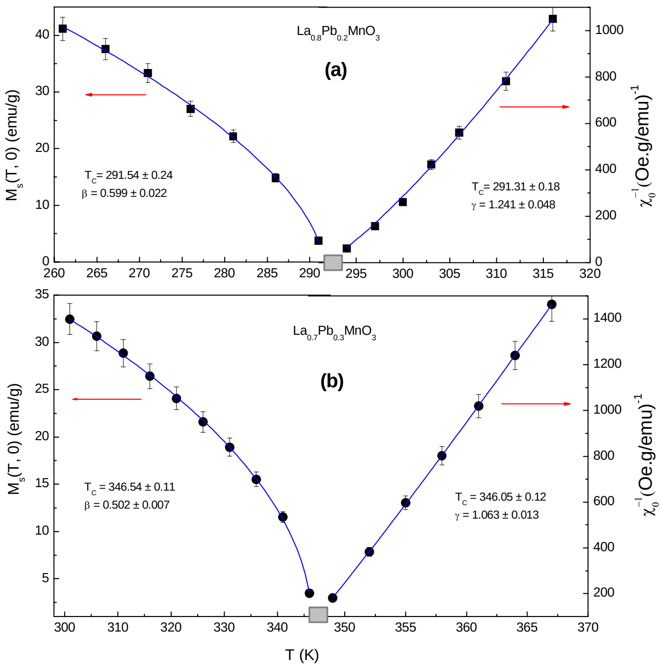

Figure 1: Temperature dependences of the spontaneous magnetization $M_s(T,0)$ and the inverse initial susceptibility $1/\chi_0(T)$ are fitted to the power laws. Error bars of 5 % are shown.

Based on the modified Arrott plots and critical isothermal analysis, and by fitting $M_s(T,0)$ and $\chi_0(T)$ data to the power laws for the phase-transition region [3], we have determined β = 0.599, $\gamma = 1.241$, $\delta = 3.07$ and $T_C \approx 291$ K for $La_{0.8}Pb_{0.2}MnO_3$, and $\beta = 0.502$, $\gamma = 1.063$, $\delta = 3.12$ and $T_C \approx 346$ K for $La_{0.7}Pb_{0.3}MnO_3$, see Figure 1. It appears from the result that with increasing the Pb concentration, T_C increases from 291 K to 346 K. This could be explained as the change in β from 0.599 (for x = 0.1) to 0.502 (for x = 0.2) that is associated with the change in interaction mechanism from the short-range ferromagnet to long-range ferromagnet where $\beta = 0.5$ (as predicted by the mean-field theory).

References

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