On unusual magnetic behavior and phase transitions of doped manganites

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Doped manganites of the chemical formula $A_{1-x}B_xMnO_3$ (A is a rare earth /La, Nd, Sm .../, and B is an alkali earth /Ca, Sr, Ba/ atom) have been extensively studied because of their rich physics [1]. Doping changes dramatically these compound leading, above a certain level, to formation of the ferromagnetic (F) ground state instead of antiferromagnetic (AF) one at x=0. With increasing x, F insulating phase usually appears which changes then for F metallic state. One of the most important peculiarities of these compounds with low T_C ($\leq$200K), when they are insulating above T_C, is a character of phase transition from paramagnetic (P) to F state. Also this transition is closely related to the colossal magnetoresistance effect, it remains to be poorly understood. It can be shown that the suggested explanations are either bankrupt [1] or unclear [2,3]. In addition, the unconventional transition is often accompanied by a paradoxical magnetic behavior in a far P region [4].

We present an approach, using a free energy Φ for the spin system only, which gives a key to explanation of these phenomena. It was successfully applied for analyzing an anomalous magnetic behavior of $Sm_{0.6}Sr_{0.4}MnO_3$ above $T_C\approx$120K [4], and we would like to present the corresponding results. This behavior is shown to be related to the appearance of the AF ordered regions as a result of the first order transition at $T\approx160K>T_C$, and their destruction by a characteristic tricritical manner with reducing temperature at $T_*\approx$138K. This explanation agrees well with a critical behavior found with nonlinear response measurements [4].

A free energy $\Phi(M)$ (where M is the magnetization) is presented to describe the unconventional P-F phase transition observed in [1-3]. A problem is that this transition has some features of the first order, for instant, a jump of M at T_C, however, it reveals no (or very weak) H-hysteresis. Moreover, according to the experimental data [2], a coefficient b at M^4 in expansion of Φ in M is positive in contradiction with the traditional model for the first order transition where b must be negative. We suggest a modification of $\Phi(M)$ which has $b>0$, and gives the first order transition with the properties corresponding to the experiments. As a preliminary analysis shows, this $\Phi(M)$ reproduced all the main peculiarities of both the unconventional P-F metallic [1-3] as well as P-F insulating [5] transitions. It suggests a common new underlying reason for transforming the conventional first order transition, that enforced by interaction of spin system with lattice in the traditional ferromagnets, into the unconventional one. This reason in doped manganites is most likely to be a coupling of spin and orbital degrees of freedom.

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