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A theoretical model of the magneto-caloric effect in manganese perovskites

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Recently, a large magneto-caloric effect (MCE) in perovskite materials has generated growing interests among scientists and manufacturers, because of its assessable and practical potential for the field of magnetic refrigeration. Nevertheless, further efforts of seeking a proper material that has a large magnetic-entropy change (ΔS_M) or a large adiabatic temperature change (ΔT_{ad}), i.e. a large MCE, in a vast variety of temperatures have been extensively devoted, but no theoretical treatments are satisfactorily made.

For a quantitative explanation, in the present work, a theoretical model, namely the molecular field model, has been proposed allowing us to interpret large magnetic entropy changes in such manganese perovskites. Accordingly, ΔS_M and ΔT_{ad} have been computed and both reach a peak at T_C, and particularly their peaks shifts to a higher temperature as the field is increasingly applied [see Fig. 1, $La_{1-x}Ca_xMnO_3$ (x=0.2, 0.3), for examples]. With respect to a given Curie temperature T_C = 227K, the maximum value of ΔS_M has been found to change as an increasing function of magnetic field [see the right panel of Fig. 2, $La_{1-x}Ca_xMnO_3$ (x=0.3), for example]. Meanwhile, at a given magnetic field (B=5T) it decreases with increasing T_C [see the inset of Fig. 2]. These obtained results are consistent with those calculated, in terms of the Maxwell's expressions, using the experimentally measured magnetization data [1-3]. In particular, satisfactory agreements between the theoretical calculations derived in the molecular field approximation and the experimental dependences for a representative sample of $La_{1-x}Ca_xMnO_3$ (x=0.2) have been found (see the right panel of Fig. 2).

In summary, the proposed theoretical model utilizing the molecular field approximations has provided a quantitative interpretation for large magnetic entropy changes, or the underlying knowledge of large MCE, in such manganese perovskites. This is very sufficient in reviewing appropriate magnetic refrigerants as using perovskite materials for magnetic refrigerators.

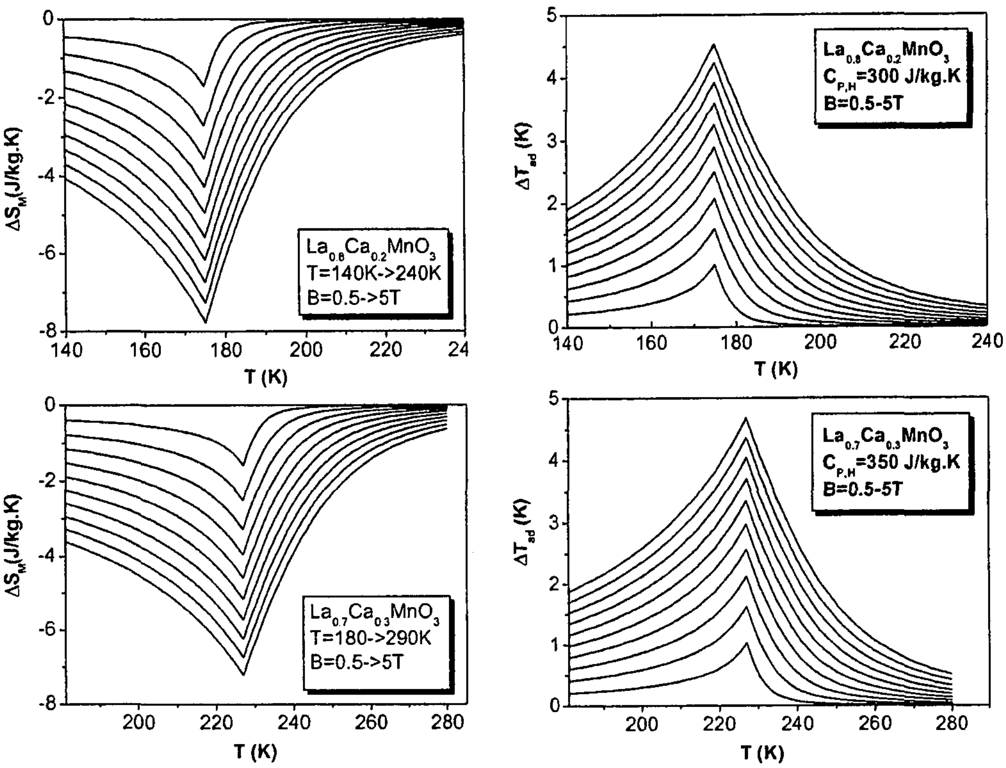

Fig. 1. *In the left panel: the magnetic entropy change (ΔS_M) as a function of temperature. In the right panel: the adiabatic temperature change (ΔT_{ad}) as a function of temperature.*

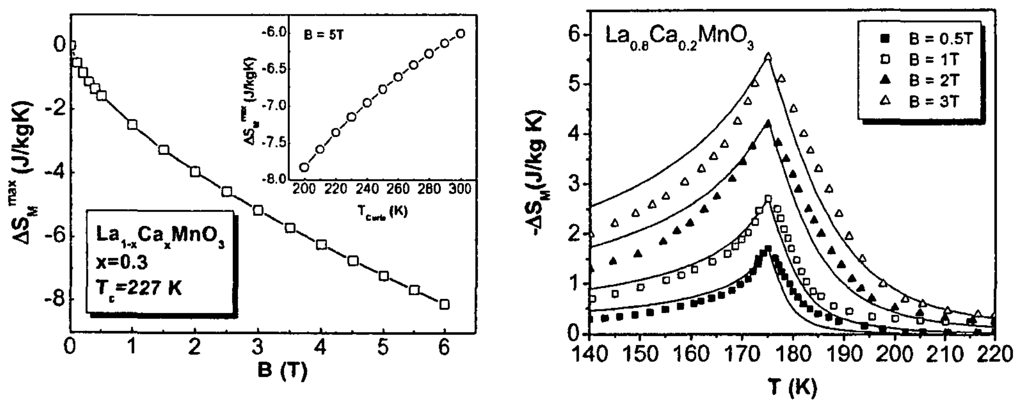

Fig. 2. *In the left panel: the magnetic entropy change (ΔS_M) as a function of magnetic field. The inset shows ΔS_M as a function of T_C. In the right panel: ΔS_M as a function of temperature (theoretical solid-line and experimental points).*

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