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Magnetic anisotropy and magnetocaloric effect in charge-ordered $Pr_{0.5}Sr_{0.5}MnO_3$

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Abstract – We have studied magnetic anisotropy and magnetocaloric effect (MCE) in charge-ordered $Pr_{0.5}Sr_{0.5}MnO_3$, which undergoes a paramagnetic to ferromagnetic transition at T_C ~255 K followed by a ferromagnetic charge-disordered to antiferromagnetic (AFM) charge-ordered transition at T_{CO} ~165 K. Our RF transverse susceptibility (TS) experiments reveal a sharp jump in magnetic anisotropy at T_{CO} and provides evidence for the existence of ferromagnetic clusters in the A-type AFM state below T_{CO} and in the PM state above T_C. MCE experiments reveal different influences of first and second-order magnetic phase transitions on the magnetic entropy and refrigerant capacity (RC) of this system.

Charge ordered manganites are of great interest as they exhibit both colossal magnetoresistance (CMR) and giant magnetocaloric (GMC) effects around a temperature where the field-induced magnetic, electron and structural phase transitions occur (from antiferromagnetic charge-ordered state to ferromagnetic charge-disordered state). However, a complete understanding of magnetic anisotropy and the relationship between these transitions and MCE in these materials is still lacking [1]. In this study, we present systematic TS and MCE experiments on charge-ordered $Pr_{0.5}Sr_{0.5}MnO_3$ compounds prepared using conventional ceramic route. Magnetic and magnetocaloric measurements were conducted using a commercial Physical Property Measurement System (PPMS) from Quantum Design with a temperature range of 5 – 300 K and applied fields up to 7 T. A sensitive tunnel-diode oscillator (TDO) operating at 12-15 MHz was used to measure the radio-frequency (RF) transverse susceptibility of this material [2]. Since the presence of the electromagnetic fields on the sample is associated with the RF currents, the TS technique is sensitive to both resistive and magnetic transitions that often simultaneously occur in charge-order manganites [3]. In particular, the magnetic screening length of the material is determined by both the effective susceptibility (μ_{eff}) and the electrical conductivity (σ) via the skin depth, $\delta = (\mu_{eff}/\sigma)^{1/2}$, where these parameters (μ_{eff} and σ) abruptly vary at a temperature at which a magnetic ordering transition or electronic phase transition takes place. Here, we demonstrate that the RF TS technique is useful for probing magnetic anisotropy and field-induced phase transitions in charge-ordered $Pr_{0.5}Sr_{0.5}MnO_3$. It is found that there is a sharp jump in magnetic anisotropy at T_{CO}, and magnetic anisotropy is persistent even in the temperature range below T_{CO} and above T_C, indicating the existence of ferromagnetic clusters in the A-type AFM state and in the PM state. Magnetic switching from the AFM state into the FM state at high magnetic fields is evidenced by the TS data. These findings provide physical insights into the underlying mechanism of complex magnetic interactions and field-induced phase transitions present in such charge ordered manganites.

MCE experiments reveal different influences of first and second-order magnetic phase transitions on magnetic entropy and refrigerant capacity (RC) of $Pr_{0.5}Sr_{0.5}MnO_3$. It is found that while the first-order magnetic transition (FOMT) at T_{CO} induces a larger MCE (6.8 J/kg K) limited to a narrower temperature range resulting in a smaller RC (168 J/kg), the second-order magnetic transition (SOMT) at T_C induces a smaller MCE (3.2 J/kg K) but spread over a broader temperature range resulting in a larger RC (215 J/kg). In addition, large magnetic and thermal hysteretic losses associated with the FOMT below T_{CO} are detrimental to efficient magnetic refrigerant capacity whereas these effects are negligible below T_C because of the second order nature of this transition. These results are of practical importance in assessing the usefulness of charge-ordered manganite materials for active magnetic refrigeration, and $Pr_{0.5}Sr_{0.5}MnO_3$ provides an interesting case study in which the influence of first and second order transitions on MCE could be compared in the same system in a single experiment.

References

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