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Manganese Perovskite Nanoparticles and the Downturn of Inverse Susceptibility above the Curie Temperature

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In the $La_{0.75}Sr_{0.25}MnO_3$ nanoparticle system for hyperthermia a downturn in the inverse susceptibility above the Curie temperature T_c was observed and interpreted in terms of a finite width of the T_c distribution.

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1. General information

The magnetic study of the nanoparticles usually comprises the determination of the ZFC and FC susceptibilities which corresponds to the measurement after zero-field and field-cooled procedures, respectively. In the present work however we focus our attention on the region above T_c, where in many bulk manganites a downturn of the inverse susceptibility was found and explained by the presence of a Griffith phase [1]. In studying the nanoparticles for hyperthermia we observed the same effect, for which the interpretation was suggested using the distribution of T_c.

2. Results and discussion

The SQUID magnetometer measurements were performed on the manganite $La_{0.75}Sr_{0.25}MnO_3$ in the form of the bulk sample (LSMOB) and two 20 nm nanoparticle samples LSMO and LSMO@SiO_2, where the second one was encapsulated in SiO_2 [2]. The temperature dependence of the magnetization M under the applied field 7.95 kA/m was measured when cooling the sample from 400 to 300 K. Well above T_c, M can be separated to a Curie–Weiss (C–W) part and a small contribution M_{imp} arising from ferromagnetic impurities. The FC susceptibility χ_g per unit of the weight and the main experimental result — the quantity $d(1/\chi_g)/dT$ (Fig. 1a) was then evaluated from the corrected values $M - M_{imp}$. In order to explain the observed downturn of $1/\chi_g$, which manifests itself in a maximum of $d(1/\chi_g)/dT$ we assume a Gauss distribution function $f(T_c)$ characterized by the average value $T_{ca} = 335$ K and a given dispersion σ, which is approximately equal to the halfwidth of $f(T_c)$. This assumption is realistic if we realize that there is a random distribution of the nanoparticle sizes and that T_c depends on the nanoparticle diameter [3]. For a given T, T_c, g-factor and spin S the reduced magnetization $M_r = M/M_0$ (M_0 is the saturated value of M for T approaching zero) and susceptibility $\chi_r = \chi/M_0$ can be calculated using the molecular field method. This procedure consists in solving the transcendental equation

$$M_r = B_S\left[Sg\mu_B(H + \lambda M_r)/k_BT\right], \qquad (1)$$

where $\lambda = 3k_BT_c/(g\mu_B(S+1))$ and $B_S(x)$ is the Brillouin function for spin S. Taking $g = 2$, $S = 5/2$ (this value approximately corresponds to the effective spin deduced from the experiments on the bulk samples) and σ as a parameter we determined M_r and finally $d(1/\chi_r)/dT$ by integrating the product $M_r(T, T_c)$ over T_c (Fig. 1b). Letting aside absolute values we shall compare the form of the curves displayed in Fig. 1a and b. For $\sigma = 0.25$ K the

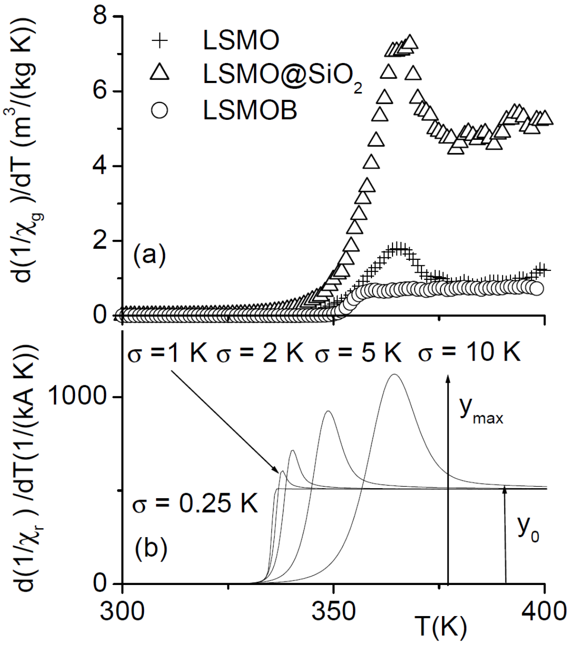

Fig. 1. The derivative $d(1/\chi_g)/dT$ from experiment (a). The calculated values of $d(1/\chi_r)/dT$ for $H = 7.95$ kA/m, $T_{ca} = 335$ K and different values of the dispersion σ (b).

calculated derivative approaches a step function (C–W behaviour) and for increasing σ the ratio $r = y_{\max}/y_0$ increases. For the bulk sample $r \to 1$ corresponding to $\sigma \to 0$. For LSMO and LSMO@SiO$_2$ $r = 2.1$ and 1.6 respectively, which suggests a narrower size distribution in the case of the sample containing the encapsulated nanoparticles.

3. Conclusion

The downturn of the inverse susceptibility above T_{c} may give an additional information about the Curie temperature and thus nanoparticle size distribution.

Acknowledgments

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