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Weak exchange bias effect in $RuSr_2GdCu_2O_{8-\delta}$-$La_{0.67}Sr_{0.33}MnO_3$ composites

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Abstract

We report the synthesis and characterization of $RuSr_2GdCu_2O_8$-$La_{0.67}Sr_{0.33}MnO_3$ superconducting-magnetic composites with 0 to 50 wt% of $La_{0.67}Sr_{0.33}MnO_3$ in the composites. Systematic measurements of magnetization as a function of applied magnetic field at up 5 kOe were performed at temperature regimes below the Curie temperature (T_C) of $La_{0.67}Sr_{0.33}MnO_3$ but above the Néel temperature (T_N) of $RuSr_2GdCu_2O_8$; below T_N of $RuSr_2GdCu_2O_8$ but above the superconducting critical temperature (T_{SC}) of $RuSr_2GdCu_2O_8$; and below T_{SC} of $RuSr_2GdCu_2O_8$. Our results reveal the ferromagnetic character of the composites at the temperature regime $T_N < T < T_C$. Exchange bias effect was observed for weak applied fields (H <1.5 kOe) at the temperature regime $T_{SC} < T < T_N$. At the superconducting temperature regime ($T<T_{SC}$) weaker exchange bias is observed for low magnetic fields (H < 0.6 kOe). For strong magnetic fields (H> 2 kOe) the ferromagnetic character of the system is recovered.

Keywords: Superconducting ruthenate, manganite, magnetic properties, exchange bias effect.

1. Introduction

The dicovery of the coexistence of the superconducting character and the antiferromagnetic (AFM) ordering in Ru-1212-type $RuSr_2GdCu_2O_8$ compound [1], has provide a opportunity for studing, in the same material, these antagonic phenomenon [2-3]. An important magnetic characteristic associated with the exchange anisotropy created at the interface between a ferromagnetic (FM) and an antiferromagnetic material occurs when materials FM (with high Curie temperature T_C) and AFM (with Néel temperature $T_N<T_C$) are cooled through the T_N [4-5]. This effect, which is known as exchange bias, produces an asymmetry in the FM hysteresis curve. In this work we present results of exchange bias effect in $RuSr_2GdCu_2O_8$-$La_{0.67}Sr_{0.33}MnO_3$ composites, prepared in sub-micrometric size grains. The observation of this effect was possible due the AFM character of the $RuSr_2GdCu_2O_8$ materials at low magnetic fields and the typical FM response of the $La_{0.67}Sr_{0.33}MnO_3$ manganites.

2. Experimental

Single phase polycrystalline samples of $RuSr_2GdCu_2O_8$ and $La_{0.67}Sr_{0.33}MnO_3$ perovskite materials were prepared by the standard solid state reaction method. Mixture 50 vol% $RuSr_2GdCu_2O_8$ and 50 vol% $La_{0.7}Sr_{0.3}MnO_3$ was solid-reacted to form the composite material. Structural and microstructural characterization of compounds and composite were performed by the X-ray diffraction technique and by Scanning Electron Microscopy (SEM). Magnetization measurements of were performed by using a QD 2000 MPMS SQUID.

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3. Results and discussion

X-ray diffractogram show two separate crystallographic phases in the composite samples without any trace chemical reaction between the respective compounds. SEM images revealed the sub-micrometric character of grains. DC Resistivity measurements showed the superconducting feature of $RuSr_2GdCu_2O_8$ with a critical temperature T_{SC} = 39.2 K. Results of magnetization as a function of temperature for the same material exhibited an AFM transition with a T_N = 132.7 K. The magnetic field dependence of the magnetization revealed the characteristic FM behavior of $La_{0.67}Sr_{0.33}MnO_3$. Figure 1 exhibits the hysteretic behavior of magnetization for $RuSr_2GdCu_2O_8$-$La_{0.67}Sr_{0.33}MnO_3$ composites at temperature values above T_N of the AFM $RuSr_2GdCu_2O_8$ but below T_C of the FM $La_{0.67}Sr_{0.33}MnO_3$ material ($T_N < T < T_C$).

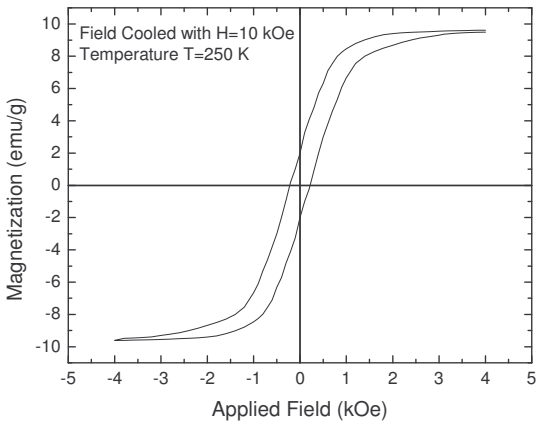

Fig. 1. Hysteretic FM behavior of $RuSr_2GdCu_2O_8$-$La_{0.67}Sr_{0.33}MnO_3$ composites at T=250 K.

At the temperature regime $T < T_N$, we observe a weak exchange bias behavior for low applied magnetic fields (H< 1.5 kOe). The characteristic asymmetric curve of this exotic phenomenon is showed in figure 2. We notice that this effect is not observed for magnetic fields higher than 2 kOe. At the superconducting regime ($T < T_{SC}$), we effectively observe a weaker exchange bias effect for low applied fields (H < 600 Oe). When the applied field is increased, we recover the FM curve characteristic of the single $La_{0.67}Sr_{0.33}MnO_3$ material. This behavior may be evidence that the AFM ordering in the $RuSr_2GdCu_2O_8$ only occurs for low magnetic fields. For high applied fields we could be expecting a competition between superconductivity and FM behavior in this interesting material.

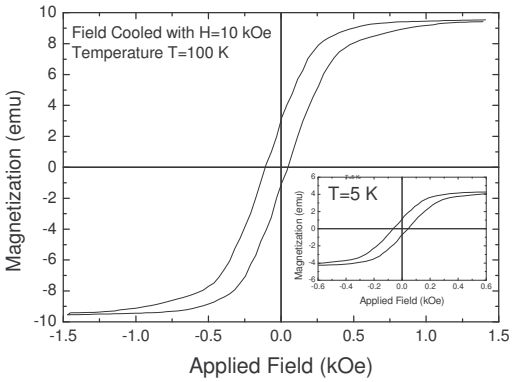

Fig. 2. Exchange bias effect of $RuSr_2GdCu_2O_8$-$La_{0.67}Sr_{0.33}MnO_3$ composites at T=100 K ($T_{SC} < T < T_N$). The inset show the very weak exchange bias observed at $T < T_{SC}$ for low magnetic fields.

4. Conclusions

We have performed a complete characterization of the magnetic of $RuSr_2GdCu_2O_8$- $La_{0.67}Sr_{0.33}MnO_3$ composites, constituted by sub micrometric grains. Due the granular interfaces between the AFM $RuSr_2GdCu_2O_8$ and FM $La_{0.67}Sr_{0.33}MnO_3$ grains, it is observed that the exchange bias effect has place for low applied magnetic fields at the $T_{SC}<T<T_N$ temperature regime. An interesting result is that of the absence of exchange bias for strong applied fields. On the other hand, the occurrence of exchange bias for low fields and the respective absence for strong fields, below the superconducting transition, is interpreted as a non conventional magnetic ordering in $RuSr_2GdCu_2O_8$ perovskite material.

Acknowledgments

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References

[1] L. Bauernfeind, W. Widder, H.F. Braun, Physica C 254 (1995) 151.
[2] J.W. Lynn, B. Keimer, C. Ulrich, C. Bernhard, J.L. Tallon, Phys. Rev. B 61 (2000) R14964.
[3] I.I. Mazin, D.J. Singh, Phys. Rev. Lett. 82 (1999) 4324.
[4] W.H. Meiklejohn, C.P. Bean, Phys. Rev. 102 (1956) 1413.
[5] S. Mangin, G. Marchal, B. Barbara, Phys. Rev. Lett. 82 (1999) 4336.