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MAGNETOTUNNELING EXPERIMENTS USING $La_{0.7}Sr_{0.3}MnO_3$ BASED BREAK JUNCTIONS

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The $La_{0.7}Sr_{0.3}MnO_3$ perovskite is a ferromagnetic half-metal with a strong spin polarization and high Curie temperature T_C (355 K). We have shown that a combination of the break junction technique with the special properties of the $La_{0.7}Sr_{0.3}MnO_3$ perovskite can lead to extremely high values of tunneling magnetoresistance ratio ($> 10^3\%$) and high field sensitivity (30%/Oe). These results are obtained in magnetic fields below 1 kOe and at room temperature.

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1. Introduction

Manganese oxide compounds with a perovskite-type structure described by the general formula of $La_{1-x}A_xMnO_3$ (A = Sr, Pb, Ca, Ba, etc.) have been widely studied in recent years because of their high-field colossal magnetoresistance (CMR) [1]. This effect is related to the intrinsic mechanism, namely the Zener "double exchange" [2]. In this mechanism the conductivity is caused by the hopping of the e_g electrons between Mn^{3+} and Mn^{4+} ions when their spins are parallel. However, most applications require strong changes of the resistance in low magnetic fields. This problem can be resolved owing to the half-metallic character of the manganites band structure [3]. Low-field CMR has been attributed to either spin-polarized tunneling [4], spin-dependent scattering [5] or micromagnetic behavior associated with alignment of the magnetic domains at the grain boundary [6].

The strong Hund coupling and the exchange energy result in a nearly 100% spin polarization of electrons. The high value of the spin polarization P leads to the large value of the tunneling magnetoresistance (TMR) described by the Julliére formula of $TMR = 2P_1P_2/(1 - P_1P_2)$, where P_1 and P_2 are spin polarizations of two magnetic electrodes [7]. The TMR effect is observed in junctions consisted of two ferromagnetic layers (electrodes) separated by an insulator and appears in low magnetic fields [3, 8]. Alternatively, the spin polarized tunneling can run between grains' boundaries of the polycrystalline material [9]. In this paper the combination of these possibilities is realized by the preparation of the tunneling "break junction", which enables a controllable modification of the intergrain distance, hence, the junction resistance.

The differential conductance $\mathrm{d}I/\mathrm{d}V$ and the $I-V$ characteristics have also been studied.

2. Experimental

The $La_{0.7}Sr_{0.3}MnO_3$ perovskites were synthesized by a standard ceramic technique. The sample was mounted on an elastic substrate immobilized at the edges and the bending force was applied to the central point of the opposite side of the substrate to create the break junction. This device enables investigation of the tunneling transport occurring between single grains of the polycrystalline perovskite.

3. Results and discussion

The tunneling effect occurs between a small number of grains located at the opposite surfaces of the break junction fracture. The increase of the device bending can lead to resistances of the order of a few MΩ, i.e., to tunneling between single grains placed within the fracture. Figure 1 shows the differential conductivity for $La_{0.7}Sr_{0.3}MnO_3$ in magnetic field of 30 Oe and 1000 Oe. The parabolic shape of the curve confirms the tunneling character of the conduction process. The Simmons [10] model of tunneling through insulator yields typical barrier heights and widths in the range of $0.2 \div 1.2$ eV and $1 \div 2$ nm, respectively. The non-ohmic behavior was confirmed for all junctions with the resistance exceeding 1 kΩ.

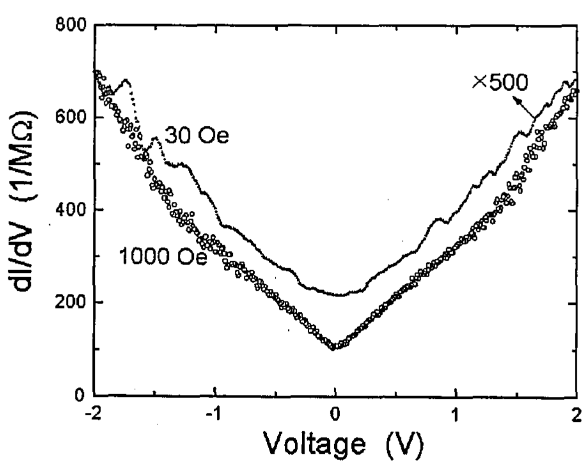

Fig. 1. Differential conductance for $La_{0.7}Sr_{0.3}MnO_3$ based break junction measured at RT in magnetic fields H of 30 Oe and 1000 Oe.

In Fig. 2 typical CMR curve (inset) for unbroken sample is compared with the TMR result for break junction. The magnetic field H is applied parallel to the fracture area in the case of the break junction. The CMR curve consists of the low field intergranular tunneling contribution and the high-field part corresponding to the intrinsic properties of the grains. The applying of the magnetic field H perpendicularly to the fracture (Fig. 3) results in higher TMR ratio ($\cong$ 600%) but, simultaneously, the saturation field is twice the value for H parallel to the fracture.

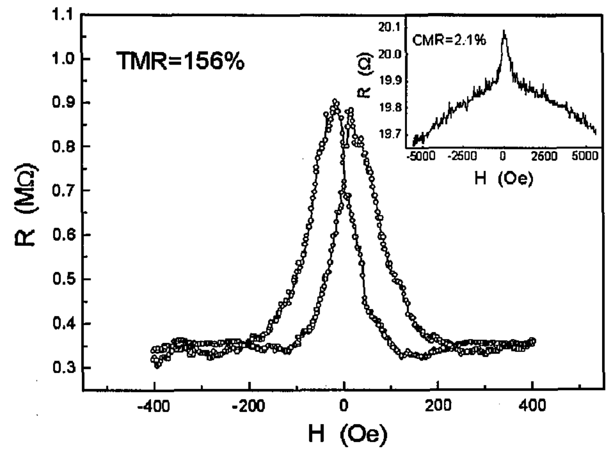

Fig. 2. Tunneling magnetoresistance for break junction with magnetic field H parallel to the fracture area at RT. The inset: Colossal magnetoresistance for unbroken polycrystalline $La_{0.7}Sr_{0.3}MnO_3$ perovskite .

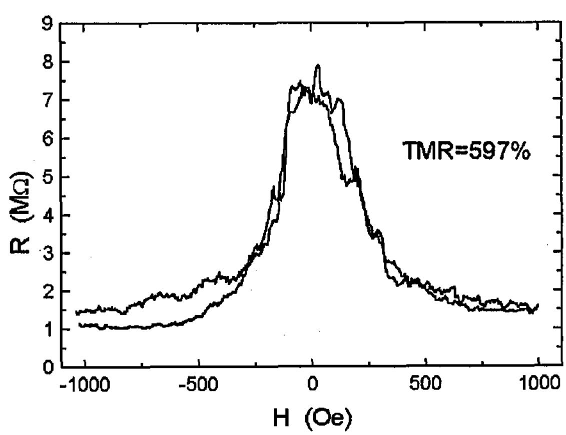

Fig. 3. Room temperature tunneling magnetoresistance for $La_{0.7}Sr_{0.3}MnO_3$ break junction with magnetic field H perpendicular to the fracture area.

Also the domain processes are more pronounced and develop different shapes of the $R(H)$ dependences for various field sweeps. The discrepancy between the two orientations of the magnetic field is probably connected with the anisotropic effects of the grains.

The tuning of the device resistance and the applied voltage give the TMR ratios exceeding several thousands percent.

4. Conclusions

The $I-V$ characteristics for $La_{0.7}Sr_{0.3}MnO_3$ based break junctions are strongly nonlinear and provide the magnetoresistance ratio of the order of 1000% at RT in relatively low magnetic fields, i.e., below 1 kOe.

The role of the magnetic field orientation as well as the domain structure has to be studied.

Acknowledgments

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References

[1] for review: A.P. Ramirez, *J. Phys., Condens. Matter* **9**, 8171 (1997).

[2] C. Zener, *Phys. Rev.* **82**, 403 (1951).

[3] M. Viret, J. Nassar, M. Drouet, J.P. Contour, C. Fermon, A. Fert, *J. Magn. Magn. Mater.* **198**, 1 (1999).

[4] H.Y. Hwang, S.-W. Cheong, N.P. Ong, B. Batlogg, *Phys. Rev. Lett.* **77**, 2041 (1996).

[5] A. Gupta, G.Q. Gong, Gang Xiao, P.R. Duncombe, P. Lecoeur, P. Trouilloud, Y.Y. Wang, V.P. Dravid, J.Z. Sun, *Phys. Rev. B* **54**, 15629 (1996).

[6] R. Mahesh, R. Mahendiran, A.K. Raychaudhuri, C.N.R. Rao, *Appl. Phys. Lett.* **68**, 2291 (1996).

[7] M. Julliére, *Phys. Lett.* **54**, 225 (1975).

[8] J.M. De Teresa, A. Barthélémy, A. Fert, J.P. Contour, R. Lyonnet, F. Montaigne, P. Seneor, A. Vaurés, *Phys. Rev. Lett.* **82**, 4288 (1999).

[9] N.K. Todd, N.D. Mathur, S.P. Isaac, J.E. Evetts, M.G. Blamire, *J. Appl. Phys.* **85**, 7263 (1999).

[10] J.G. Simmons, *J. Appl. Phys.* **34**, 1793 (1963).