MAGNETIC ANISOTROPY IN $La_{0.8}Sr_{0.2}MnO_3$: ELECTRON SPIN RESONANCE *

J. Deisenhofer†, H.-A. Krug von Nidda, A. Loidl

Experimentalphysik V, EKM, Institut für Physik, Universität Augsburg
D-86135 Augsburg, Germany

M.V. Eremin, V.A. Ivanshin

Kazan State University, 420008 Kazan, Russia

T. Kimura and Y. Tokura

Department of Applied Physics, University of Tokyo, Tokyo 113-0033, Japan

(Received July 10, 2002)

We report on Ferromagnetic-Resonance experiments in a single crystal of $La_{0.8}Sr_{0.2}MnO_3$ in the temperature range from 4 to 300 K. The observed anisotropy of the resonance line changes on crossing the transition from the orthorhombic O-phase to the rhombohedral R-phase at $T \approx 100$ K and indicates a reorientation of the spins at about 130 K.

PACS numbers: 76.30.–v, 76.50.+g, 75.30.Vn, 75.60.–d

1. Introduction

The importance of magnetic inhomogeneities in understanding the complex phase diagrams of manganite systems like $La_{1-x}Sr_xMnO_3$ [1] becomes more and more evident, only to mention phase separation scenarios, chemical inhomogeneities or the recent description of the Colossal Magneto Resistance effect as a Griffith phase [2]. Electron Spin Resonance not only proves a very efficient tool in investigating phenomena like orbital ordering or inhomogeneities in the paramagnetic phase [3], but it is also very sensitive to changes in the magnetization behavior in the magnetically ordered regime [4–6].

The details of the experimental setup and measurement procedures are described *e.g.* in [3]. The single crystal of $La_{0.8}Sr_{0.2}MnO_3$ has been grown by the floating zone method described by Urushibara and coworkers [1]. A

* Presented at the International Conference on Strongly Correlated Electron Systems, (SCES 02), Cracow, Poland, July 10–13, 2002.

† Corresponding author: joachim.deisenhofer@physik.uni-augsburg.de

thin disc parallel to the (001)-plane has been prepared in order to control demagnetization effects. We measured at X-band frequency (9.4 GHz) and rotated the sample with the external magnetic field $\boldsymbol{H}$ applied within the disc's plane (see inset of Fig. 1(c)).

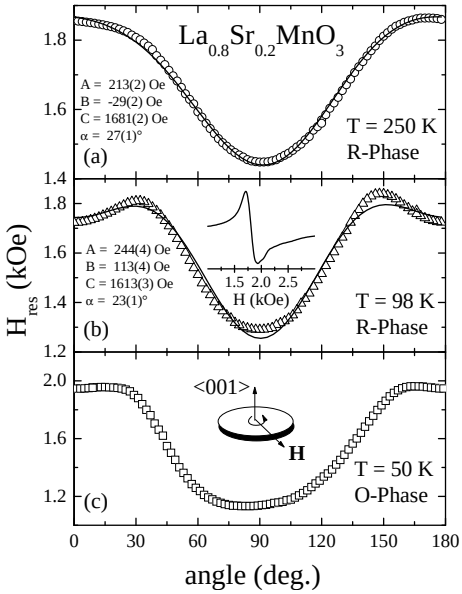

Fig. 1. Angular dependence of $H_{\rm res}$ at (a) 250 K, (b) 98 K and (c) 50 K revealing changes in symmetry with temperatures. Inset of (b) shows the field derivation of the Ferromagnetic-Resonance absorption. The solid lines are fits using equation (1).

2. Experimental results and discussion

The resonance spectra (a typical one is shown in the inset of Fig. 1(b)) reveal distortions of the main resonance above the resonance field similar to the ones observed in [5]. We fitted the main resonance line with a Lorentzian lineshape and observed an anisotropy in both the linewidth and the resonance field $H_{\rm res}$. The latter is shown in Fig. 1 for three different temperatures: At about 95 K (upon heating) the system changes from orthorhombic (O-phase) to rhombohedral symmetry (R-phase). The transition to the paramagnetic state takes place at $T_{\rm C} \approx 310$ K. In the O-phase at 50 K a twofold symmetry with an asymmetric broad minimum is found, which can be attributed to the deviation of the orthorhombic axes from cubic symmetry.

Right above the structural transition at 98 K we observe an anisotropy which we describe by a superposition of a fourfold and a twofold symmetry using

$$H_{\rm res}(\phi) = A\sin(2\phi) + B\sin(4(\phi-\alpha)) + C, \qquad (1)$$

where ϕ denotes the rotation angle in the (001)-plane. Far above the transition at 250 K again a twofold symmetry is found, indicating a uniaxial magnetocrystalline anisotropy. The fit with Eq. (1), however, includes still a fourfold contribution. The fits and fitparameters are shown in the corresponding panels of Fig. 1. Besides the fact that the dominant uniaxial anisotropy parameter A decreases, the fourfold parameter B even becomes negative, indicating a change of hard and easy axes between 98 K and 250 K within the R-phase. A fourfold symmetry has also been reported by Viglin *et al.* [5] yielding anisotropy fields of $H_{A_1} \approx 130$ Oe by fitting with the usual angular dependence of cubic symmetry in the cube face plane [7]. The low value of $C \approx 1.6$ kOe in contrast to the resonance observed in a sphere [5] can be explained by taking into account the demagnetization effects for a disc [7]. Moreover, Szymczak *et al.* [4] report on FMR and magnetization measurements in the (110)-plane revealing an uniaxial magnetocrystalline anisotropy and a change of the easy and hard directions concomitantly to the structural transition.

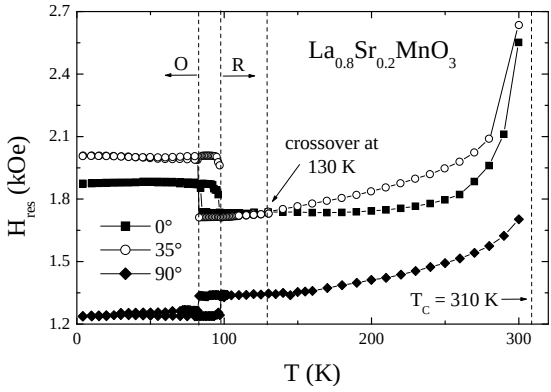

Fig. 2. Temperature dependence of $H_{\rm res}$ with the external magnetic field applied parallel to the directions of the three extrema from Fig. 1.

Therefore we measured the temperature dependence of the resonance line with the external field parallel to the three extrema at 0°, 35° and 90° determined from the angular dependence in Fig. 1(b). The temperature dependence of $H_{\rm res}$ for all three directions is shown in Fig. 2: The anisotropy in the O-phase is almost constant for $T < 80$ K, whereas for 80 K $< T <$ 95 K a hysteretical behavior is observed, which reportedly accompanies the structural phase transition from orthorhombic to rhombohedral symmetry [4]. The R-phase is characterized by a decrease in anisotropy and only within the narrow temperature range of 95 K $< T <$ 130 K the angular dependence exhibits the three extrema as seen in Fig. 1(b). For $T > 130$ K the angular dependence reveals a twofold symmetry as in Fig. 1(a). In the

temperature dependence this change is indicated at the crossover of the data for 0° and 35°. Towards the magnetic transiton a shift of the resonance to higher fields is observed for all three directions, which is due to the decrease of the magnetization on approaching T_C.

3. Conclusion

In conclusion, we found that the anisotropy in the ferromagnetic (001)-plane can be interpreted as a superposition of a cubic fourfold symmetry and a twofold symmetry due to anisotropic ferromagnetic superexchange interactions like in $LaMnO_3$. The fourfold contribution is strongest just above the structural transition, where the system tends to restore cubic symmetry. The spin-reorientation is found to take place at 130 K far above the structural transition.

We are grateful to V. Tsurkan for help with the preparation of the disc. This work was supported in part by the BMBF under contract no. 13N6917 (EKM), by the Deutsche Forschungsgemeinschaft (DFG) via the SFB 484 and DFG-project No. 436-RUS 113/566/0, and by INTAS (project no 97-30850). The work of M.V.E was partially supported by RFBR grant no. 00-02-17597 and NIOKR Tatarstan. M.V.E. und V.A.I. were supported in part by the Swiss National Science Foundation (grant no. 7SUPJ062258).

REFERENCES

[1] A. Urushibara *et al.*, *Phys. Rev.* **B51**, 14103 (1995); J.-S.Zhou *et al.*, *Phys. Rev. Lett.* **79**, 3234 (1997); M. Paraskevopoulos *et al.*, *J. Magn. Magn. Mat.* **211**, 118 (2000).

[2] E. Dagotto *et al.*, *Phys. Rep.* **344**, 1 (2001); T. Shibata *et al.*, *Phys. Rev. Lett.* **88**, 207205 (2002); M.B. Salamon *et al.*, *Phys. Rev. Lett.* **88**, 197203 (2002).

[3] V.A. Ivanshin *et al.*, *Phys. Rev.* **B61**, 6213 (2000); in *Vibronic Interactions: Jahn–Teller Effect in Crystals and Molecules*, M.D. Kaplan and G.O. Zimmermann (eds.), Kluwer 2001, p. 317; J. Deisenhofer *et al.*, *Phys. Rev.* **B65**, 104440 (2002).

[4] A. Asamitsu *et al.*, *Phys. Rev.* **B54**, 1716 (1996); R.I. Zaĭnullina *et al.*, *JETP. Lett.* **74**, 115 (2001); H. Szymczak *et al.*, *J. Mag. Mag. Mat.* **242-245**, 713 (2002).

[5] N.A. Viglin *et al.*, *Phys. Sol. State* **43**, 1934 (2001).

[6] A. Pimenov *et al.*, *Phys. Rev.* **B62**, 5685 (2000); D. Ivannikov *et al.*, *Phys. Rev.* **B65**, 214422 (2002).

[7] A.G. Gurevich, G.A. Melkov, *Magnetization Oscillations and Waves*, CRC Press, Boca Raton 1996.