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Angaben zur Veröffentlichung / Publication details:

Mukhin, A. A., V. Yu. Ivanov, V. D. Travkin, S. P. Lebedev, Andrei Pimenov, Alois Loidl, and A. M. Balbashov. 2000. “Effect of weak Sr doping on antiferromagnetic resonance in La1-xSrxMnO3.” *Physica B* 284-288: 1414–15.
https://doi.org/10.1016/S0921-4526(99)02612-5.

Effect of weak Sr doping on antiferromagnetic resonance in $La_{1-x}Sr_xMnO_3$

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The observation of the colossal magnetoresistance in doped manganates $R_{1-x}A_xMnO_3$, where R is a rare-earth ion and $A = Ca^{2+}$, Sr^{2+} [1,2] has attracted considerable interest to these compounds. Their properties exhibit a remarkable variation with doping level. Magnetic excitations in these compounds are also strongly effected by the Sr (Ca) doping. Recent inelastic-neutron scattering [3,4] and submillimeter [5] studies have revealed spin excitations in $LaMnO_3$ consistent with the antiferromagnetic layer A_yF_z structure and they dramatically change with 5% Ca (Sr) doping. In this work, we performed a systematic investigation of the AFMR in single crystals of an $La_{1-x}Sr_xMnO_3$ with a low doping level.

Single crystals of $La_{1-x}Sr_xMnO_3$ ($0 < x < 0.1$) were grown by a floating zone method. Transmission $T(\nu)$ spectra of thin plane-parallel plates with a thickness about 1 mm were measured in the frequency range $\nu = 2$–$25\ cm^{-1}$ by means of quasi-optical submillimeter backward-wave-oscillator technique [6] at temperatures 3–300 K.

A common feature of the $T(\nu)$ spectra (Fig. 1) is the existence of the periodic oscillations due to an interference of a radiation inside a plane-parallel plate. On the background of these oscillations pronounced absorption lines were observed below T_N, which were identified with F and AF AFMR modes. Due to a twin structure of the crystals both the modes were excited simultaneously in the same polarization of the radiation despite a strong difference of their excitation conditions: $h \| a$-, b-axis for F-mode and $h \| c$-axis for AF-mode [5]. The only composition, which practically did not contain the twins, was the b-cut $x = 0.05$ sample, which showed the expected excitations (Fig. 1).

A remarkable feature of the mode behavior is a strong decrease of the F-mode frequency with increasing x while the AF-mode frequency is only slightly decreased (Fig. 2). We note an apparent correlation of the increasing of magnetization M_s with the fall of the F-mode (Fig. 2), which reflects its transformation to a ferromagnetic resonance mode and is accompanied by the increase of the

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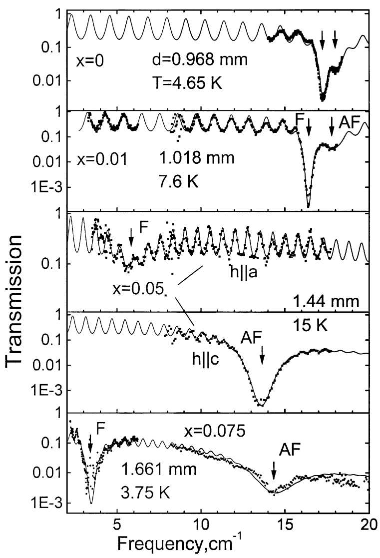

Fig. 1. Low-temperature transmission spectra of $La_{1-x}Sr_x$-MnO_3 for different concentrations. Arrows indicate F and AF modes; (points) experiment, (lines) fit by Fresnels formulas for the $T(\nu)$ with the Lorenz model for a magnetic permeability dispersion.

F-mode intensity. The observed increase of the AF-mode intensity at larger x (Fig. 1) is due to the twin structure, which reduces it for $x = 0$ and 0.01. For $x > 0.075$ the AF-mode disappeared.

We have analyzed the observed mode behavior in a frame of the de Gennes model [7], which predicts a canted magnetic structure. In addition, a single ion anisotropy $(D_x \Sigma_i S_{xi}^2 + D_z \Sigma_i S_{zi}^2)$ and the antisymmetric exchange $(\Sigma_{i,j} \boldsymbol{d}_{ij}[\boldsymbol{S}_i \boldsymbol{S}_j])$ were taken into account and a linear concentration dependence of the effective exchange and anisotropy constants was introduced. The calculated concentration dependencies of the AFMR frequencies and M_s for $T = 0$ describe their main features observed in our experiment and predict $A_y F_z - A_z F_y$ spin reorientation near $x = 0.09$ marked in Fig. 2 by an arrow. The predicted F-mode intensity is increased with x, while the AF-mode intensity is only slightly increased for $x < 0.1$ and dramatically decreased for $x > 0.1$ in agreement with the experiment.

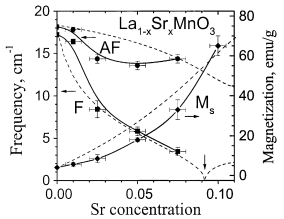

Fig. 2. Concentration dependence of the low-temperature resonance frequencies of the F- and AF-modes (left scale) and spontaneous magnetization M_s (right scale). (Points and solid lines) experiment, (dashed lines) theory.

Acknowledgements

This work was supported in part by RFBR (99-02-16849 and 97-02-17325) and INTAS (97-30850).

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