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Magnetoresistance of Polycrystalline $La_{0.7}Ca_{0.3}MnO_3$ Films in a Microwave Magnetic Field

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We present new experimental evidence indicating the importance of magnetic field component of microwave field ($f = 9.4$ GHz) for magnetoresistive properties of polycrystalline $La_{0.7}Ca_{0.3}MnO_3$ films. The microwave measurements revealed a different character of the temperature-dependent electrical resistance of polycrystalline $La_{0.7}Ca_{0.3}MnO_3$ films placed in the centre (maximal amplitude of H_{10} wave vector) and at a narrow wall of the waveguide (reduced H_{10} amplitude). Theoretical estimations of the influence of substrate onto distribution of microwave electric and magnetic fields in the waveguide were performed using the finite-difference time-domain method.

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1. Introduction

Rare-earth manganites demonstrate unusual electrical properties due to a strong interplay between spin, charge, and orbital degrees of freedom. During the last years, major attention was paid to electrical resistance change of both manganite films of various crystalline quality and related heterostructures by applying a permanent magnetic field (colossal magnetoresistance, tunneling magnetoresistance, grain boundary magnetoresistance, etc.). Recent transport investigations of polycrystalline manganite films placed in a microwave electrical field gave insightful information about their grain boundaries [1]. However, up to now, microwave

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radiation-induced resistance change of the manganite films was studied taking into account a key role of high frequency electric field for electrical properties of the manganites rather than that related to a high frequency magnetic field component.

In this paper we present experimental results demonstrating a role of both the microwave electric and magnetic fields for resistance change of polycrystalline manganite films placed in various positions in a rectangular waveguide.

2. Samples and experimental procedure

The $La_{0.7}Ca_{0.3}MnO_3$ (LCMO) films with a typical thickness about 200 nm were grown *in situ* at 750°C by pulsed laser deposition onto polycrystalline ZrO_2-buffered Al_2O_3. The evaporated Zr coatings were oxidized in pure oxygen for 2 h at 1100°C and finally cooled down to a room temperature.

The Nd^{3+} YAG laser used for LCMO film deposition operated in a doubled frequency mode (λ = 532 nm). Energy and duration of laser pulses were 25–50 mJ and 8–10 ns, respectively. After deposition, the LCMO films were annealed at 750°C for 30 min in oxygen ambient at 1 atm pressure (for 3 hours) followed by slow cooling down to room temperature. X-ray diffraction (XRD) measurements revealed a fine-grain structure of the manganite films with misaligned (100), (111), and (110) grains.

Thin LCMO film stripes with 9 mm in length and about 2 mm in width were further prepared for the electrical investigations. Couples of silver coating pads of 1 mm width were magnetron sputtered onto the films to prepare low contact resistance electrodes both for dc and microwave measurements.

Low-frequency ($f \approx$ 130 Hz) electrical transport measurements were performed in a wide temperature range (78–300 K) using a two-probe ac technique. A driving ac current of about 1 μA was used for the investigations.

For the microwave measurements, the samples were placed at various positions of the waveguide. An electrical component of the microwave field was parallel to the film surface. The pulsed microwave radiation with frequency of 9.4 GHz, pulse duration of 2 μs, repetition rate of 40 Hz, and maximal power up 5 kW was applied. The microwave response of the samples was measured by a digital oscilloscope using dc bias current of 40 μA and the load resistor (R_L = 110 kΩ) connected in series. Temperature of the samples controlled by a copper/constantan thermocouple was stabilised by a certain fixed liquid nitrogen vapour flow.

3. Results and discussion

Temperature dependences of microwave radiation (P_{MW} = 800 W) induced resistance change of polycrystalline LCMO manganite film under applied magnetic field (B = 0.4 T) and without it are presented in Fig. 1. A decrease in the electrical resistance during the microwave pulse was observed for the polycrystalline $La_{0.67}Ca_{0.33}MnO_3/ZrO_2/Al_2O_3$ films in the whole temperature range,

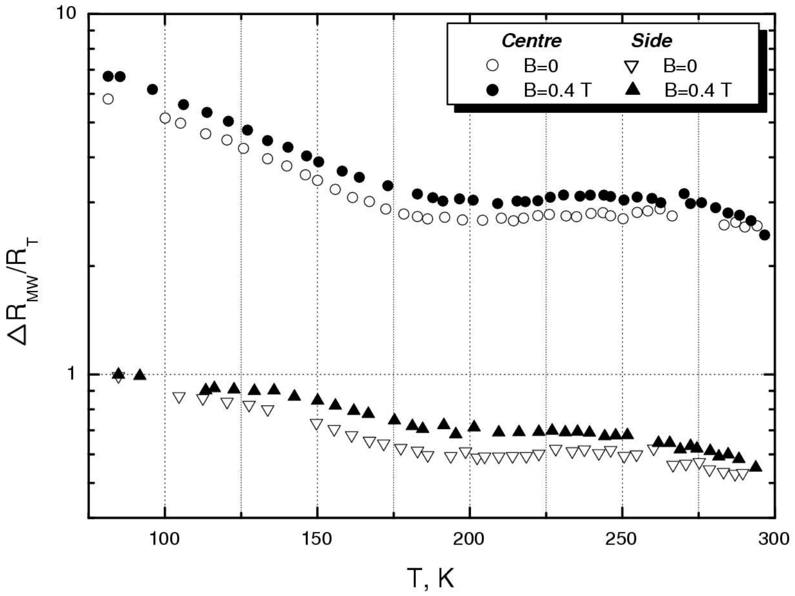

Fig. 1. Temperature dependence of the resistance change of polycrystalline $La_{0.67}Ca_{0.33}MnO_3/ZrO_2/Al_2O_3$ manganite film under influence of microwave radiation in the presence and absence of magnetic field $B = 0.4$ T.

i.e. both above and below the paramagnetic–ferromagnetic (PM–FM) transition temperature.

Open points and triangles in Fig. 1 represent temperature dependences of the microwave-induced (MW-induced) resistance change at $B = 0$ when the sample was placed in the centre of the rectangular waveguide (with narrowed cross-section 3.4 mm × 23 mm) and at its narrow wall, respectively. Similar dependences under influence of permanent magnetic field $B = 0.4$ T are depicted in the same figure by solid points. We see that the value of resistance change of the manganite film at room temperature (when the sample is placed in the centre of waveguide) is five times greater than that at the wall. This difference was slightly greater at liquid nitrogen temperature. The applied external permanent magnetic field had only negligible influence on the microwave driven electrical resistance change both for the sample placed at the centre and at the side of the waveguide.

A nonbolometric character of the resistance response can be explained within a model based on tunneling of carriers through intergrain boundaries [2]. The height of the intergrain potential barriers may, probably, be controlled by external factors temperature, pressure, etc. and also by applying a permanent magnetic field.

Figure 2 depicts temperature dependence of the electrical resistance change for LCMO film of 200 nm thickness when the sample is placed in the centre of the rectangular waveguide (open triangles). After moving the sample towards the

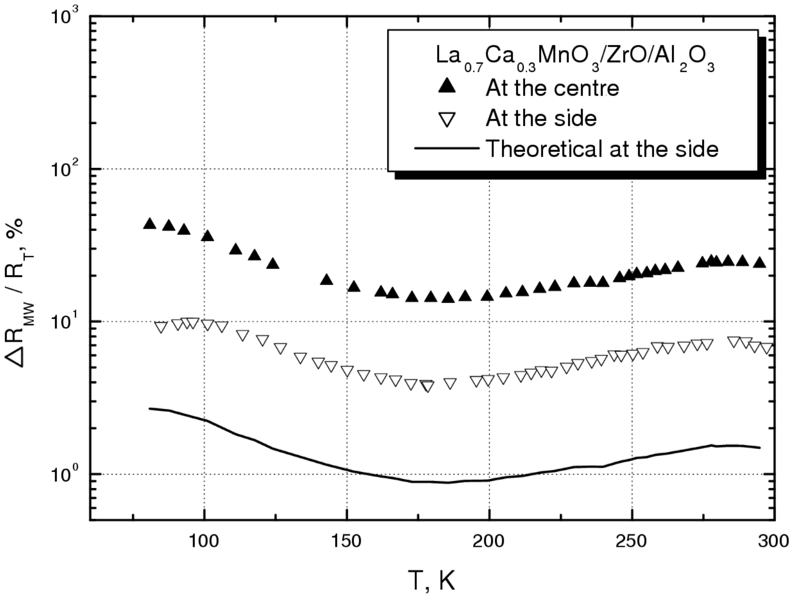

Fig. 2. Temperature dependence of microwave radiation induced resistance change measured for polycrystalline manganite film placed at various positions in rectangular waveguide.

narrow wall of the waveguide (where the electrical component E_y is significantly lower), the resistance change decreased by a factor of 6. However, the estimation of the resistance change with respect to only E_y component of the electromagnetic wave near the narrow wall gave a fifteen times lower value of the resistance change (solid line in Fig. 2). The greater value of the resistance change of the polycrystalline LCMO film placed at the side of the waveguide indicates the influence of other components of microwave electromagnetic radiation on magnetoresistance of the manganite film.

This statement is confirmed by our preliminary theoretical estimations of electrical and magnetic components of microwave signal for various sample positions in the waveguide using the finite-difference time-domain (FDTD) method [3]. This method computes the components of electromagnetic fields at given points of the grid which are shifted by half of the step from each other. Thus Maxwell's equations (in partial differential form) are modified to central-difference equations. The equations are solved in a leapfrog manner: the electric and magnetic fields are calculated at different time moments shifted in time domain by a half of time step. A few periods of oscillations are modelled until stationary solution is obtained.

This method shows a slight spatial perturbation of electromagnetic field by a massive substrate with typical dimensions of 2×9 mm. E_y and H_z components of the electromagnetic wave at various positions in the waveguide have been calculated in this work. Figure 3a shows that the electrical component is modified by the

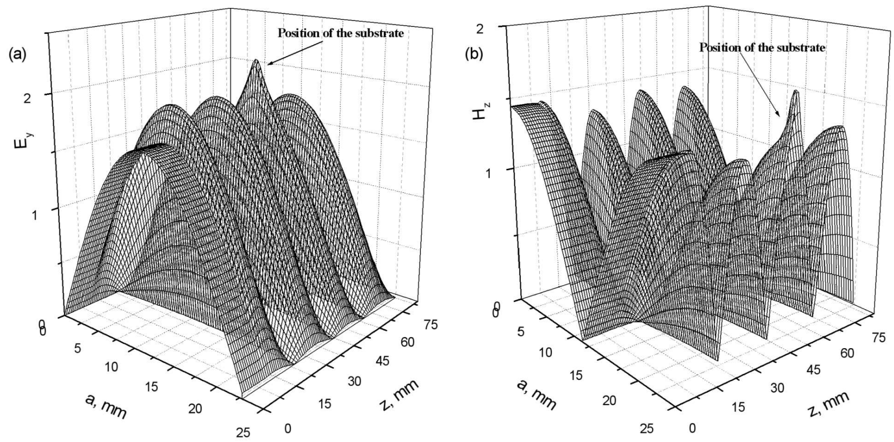

Fig. 3. Theoretical calculation of the E_y (a), H_z (b) components (in arbitrary units) of microwave radiation for various positions of the substrate in a rectangular waveguide.

substrate mainly at the centre and the magnetic component (see Fig. 3b) should be changed at the side of the waveguide. This can probably explain a certain discrepancy of experimental data and theoretical estimations of the contribution of E_y and H_z components onto resistance change of the sample.

4. Conclusions

The nonbolometric character of the resistance decrease under influence of microwave radiation observed in this work for polycrystalline LCMO films has been explained within a model based on tunneling of carriers through intergrain boundaries. The microwave electric field induced resistance change of polycrystalline manganite films depended on a sample position in the waveguide. Near the narrow wall of the waveguide, the longitudinal microwave magnetic component is of significant importance for magnetoresistive properties of the polycrystalline manganite films.

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References

[1] S. Ašmontas, F. Anisimovas, S. Balevičius, P. Cimmperman, J. Gradauskas, A. Lučun, V. Stankevič, A. Sužiedėlis, B. Vengalis, N. Žurauskienė, *Acta Phys. Pol. A* **107**, 193 (2005).

[2] P. Cimmperman, V. Stankevič, N. Žurauskienė, S. Balevičius, F. Anisimovas, J. Paršeliūnas, O. Kiprijanovič, L.L. Altgilbers, *Acta Phys. Pol. A* **105**, 107 (2004).

[3] A. Taflove, *Computational Electrodynamics: The Finite-Difference Time-Domain Method*, Artech House, Norwood, MA 1995.