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NEUTRON DIFFRACTION STUDY OF FERROMAGNETIC ORDERING IN $La_{1/3}Nd_{1/3}Ca_{1/3}MnO_3$ INDUCED BY ELECTRIC FIELD

J. Baszyński[a], B. Idzikowski[a], T. Toliński[a] and A. Hoser[b]

[a]Institute of Molecular Physics, Polish Academy of Sciences
Smoluchowskiego 17, 60-179 Poznań, Poland
[b]Hahn–Meitner Institut, Glienicker Strasse 100, 14109 Berlin, Germany

We used the neutron diffraction technique to study the ferromagnetic ordering process in $La_{1/3}Nd_{1/3}Ca_{1/3}MnO_3$ induced by the short impulse of the external electric field $E = 4$ V/cm at a magnetic field $H = 1.5$ T. Our sample was prepared by the standard solid-state reaction. The diffraction measurements at 4 K, carried out for the neutron wavelength $\lambda = 0.2442$ nm, have revealed the orthorhombic perovskite structure with the unit-cell parameters: $a = 0.5480$ nm, $b = 0.5550$ nm and $c = 0.7737$ nm. We observed that a short impulse of the electric field develops the ferromagnetic ordering in a similar way as the magnetic field up to 4 T. We assume that the increased ferromagnetic ordering induced by the external electric field at a given magnetic field has the same physical origin as in the case of the Zener double exchange. The effect is confirmed by magnetic moment measurements using vibrating sample magnetometer.

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1. Introduction

In doped perovskite manganites a strong correlation between the magnetic structure and the electrical transport properties exists which is related to the transition from the antiferromagnetic (AFM) insulator to the ferromagnetic (FM) metal.

Some intrinsic physical properties have been discovered, such as a magnetic-field induced antiferromagnetic insulator-to-ferromagnetic metal transition [1] and in particular, the coexistence of interacting AFM and FM subsystems in La-manganates [2, 3]. The physics of this transition has been explained by the double exchange [4], a process in which the e_g electron hops between Mn^{3+} and Mn^{4+} ions. In this process the e_g electrons retain the spin direction tending thereby to align the spins of neighboring Mn ions due to a strong Hund coupling.

The influence of the electric field on the shape of hysteresis loops was reported in our previous paper [5]. The field induced magnetic transition at the threshold field H_t is evident from the magnetization isotherms measured by vibrating sample magnetometer and shown in Fig. 1. This indicates a metamagnetic transition from antiferromagnetic to ferromagnetic state. The large hysteresis implies that the metamagnetic transition is accompanied by a significant structural change of the lattice. The value of H_t decreases after applying the electric field.

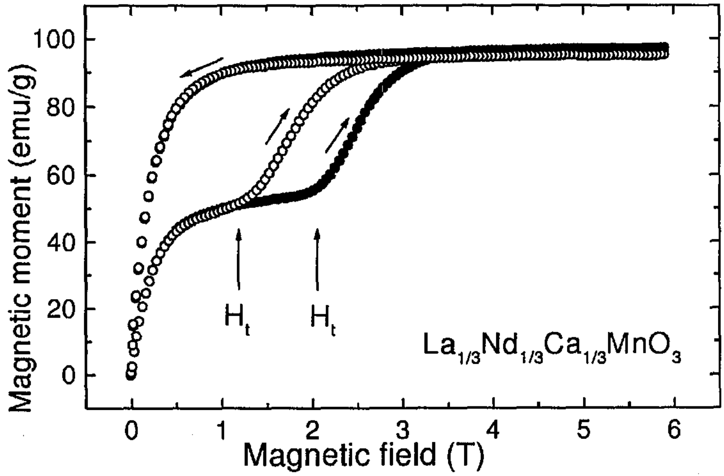

Fig. 1. Magnetic and electric field dependence of the magnetic moment at $T = 4.2$ K for $La_{1/3}Nd_{1/3}Ca_{1/3}MnO_3$. Solid and open symbols denote runs without electric field and in $E = 4$ V/cm, respectively. The arrows mark the threshold field H_t [5].

We used the neutron diffraction technique to make comparison studies of the effect of FM ordering induced by the magnetic and the electric field at temperature of 4.2 K.

2. Experimental

The sample with the nominal composition $La_{1/3}Nd_{1/3}Ca_{1/3}MnO_3$ was prepared by the standard solid-state reaction method. A stoichiometric mixture of La_2O_3, Nd_2O_3, $CaCO_3$, and $MnCO_3$ was calcined at 940°C for 8 h in air. The product thus obtained was reground, pelletized and sintered at 1250°C for 6 h in air and annealed at 1000°C for 24 h in flowing oxygen. The neutron diffraction measurements at 4 K (Fig. 2) carried out for the neutron wavelength $\lambda = 0.2442$ nm revealed the orthorhombic perovskite structure with the unit-cell parameters: $a = 0.5480$ nm, $b = 0.5550$ nm and $c = 0.7737$ nm.

3. Results and discussion

We report on the study of a new effect in $La_{1/3}Nd_{1/3}Ca_{1/3}MnO_3$ — the increased FM ordering induced by a short impulse of the external electric field $E = 4$ V/cm at the magnetic field $H = 1.5$ T and the temperature $T = 4$ K. It is seen that the electric field applied at $H = 1.5$ T causes effect similar to the increase

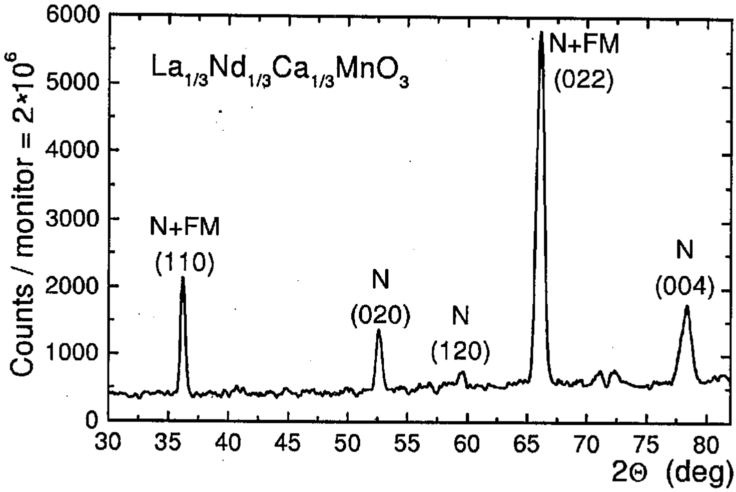

Fig. 2. Neutron powder diffractogram of polycrystalline $La_{1/3}Nd_{1/3}Ca_{1/3}MnO_3$ perovskite at 4 K (N and FM are nuclear and ferromagnetic peaks, respectively).

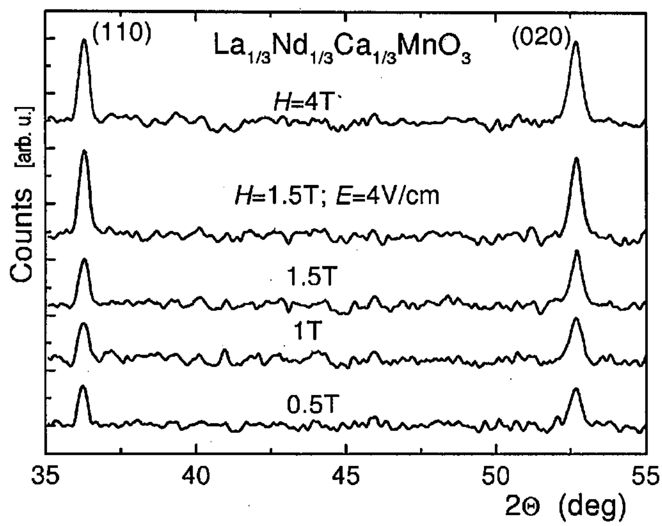

Fig. 3. Magnetic contributions to the nuclear reflections induced by the magnetic and electric fields for $La_{1/3}Nd_{1/3}Ca_{1/3}MnO_3$ perovskite at temperature of 4 K.

in the magnetic field from 1.5 T up to 4 T (Fig. 3). The magnetic contribution to the allowed (110) and (020) nuclear reflections is shown in Fig. 3. All magnetic features can be indexed in the chemical unit cell. Figure 4 displays the dependence of the integrated intensity of the magnetic peaks on the magnetic field H. This result is consistent with the magnetic measurements shown in Fig. 1.

We assume that in the $La_{1/3}Nd_{1/3}Ca_{1/3}MnO_3$ perovskite the increased FM ordering induced by the external electric field at a given magnetic field has the same physical origin as in the case of the Zener double exchange mechanism [4]. This new effect can be attributed to a strong coupling between the spins of the

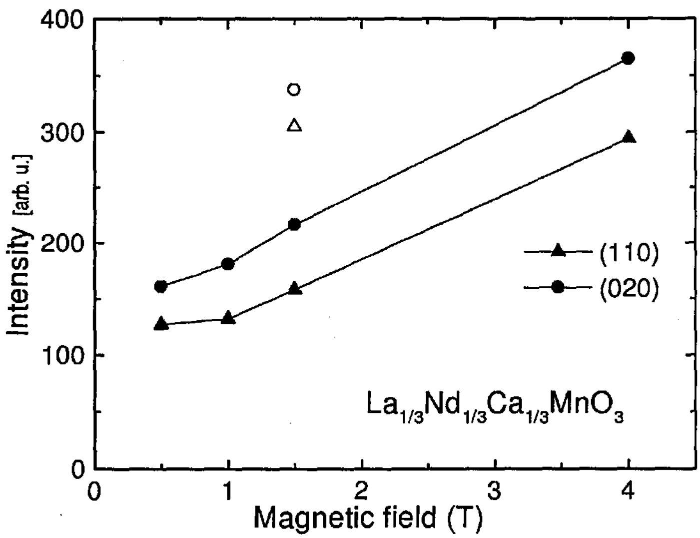

Fig. 4. Magnetic peak areas of the (110) and (020) peaks for $La_{1/3}Nd_{1/3}Ca_{1/3}MnO_3$ as a function of the magnetic and electric fields. Two open symbols were measured after short electric field impulse $E = 4$ V/cm.

hopping e_g-electrons (carriers created via electric field) and the local magnetic moments of the manganese ions (t_{2g}-localized spins).

4. Conclusions

We have shown that the magnetic field inducing the phase transitions in Mn-based perovskites decreases after application of the electric field E. This effect can be useful from the point of view of potential applications in magnetic sensors.

Acknowledgments

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