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Magnetoelectric response of new Sr_2TiMnO_6 manganite-like material

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Abstract

We report synthesis and characterization of new Sr_2TiMnO_6 manganite-like material. Samples were produced by the solid state reaction method. X-ray diffraction experiments reveal the presence of peaks, which are characteristics of the complex perovskite systems. Rietveld refinement showed that Sr_2TiMnO_6 crystallizes in a tetragonal structure, which corresponds to the space group I/4m. From measurements of magnetization as a function of temperature, we determine the occurrence of magnetic ordering for a critical temperature $T_C = 44.8\,K$ and strong evidence of frustration. Curves of magnetization as a function of applied field show hysteretic behavior. Curves of polarization as a function of applied voltage exhibit the ferroelectric response of Sr_2TiMnO_6 material. Results reveal the occurrence of magnetoelectric response for the temperature regime $T<44.8\,K$.

Keywords: New material; Magnetoelectric behavior; Complex perovskite

1. Introduction

In recent years, a great many studies of perovskite ceramics have been carried out with the objective to find materials that show magnetic and electric coupled properties for applications in the magnetoelectronics technology such as non-volatile memories [1–3]. These materials that combine spontaneous magnetization and spontaneous ferroelectric polarization have been called multiferroics [4]. Although the comprehension of the mechanisms that favor the interaction between electric and magnetic order parameters is not yet absolutely established, there is great interest in the study of the magnetoelectric materials because the introduction of an additional degree of freedom gives the possibility to manipulate multifunctional devices through more than one physical field. Particularly, coupling between ferroelectric and ferromagnetic order parameters allows the possibility of tuning the magnetization response of magnetoelectric material by means an applied electric field and vice versa.

In order to investigate the possibility to assemble a magnetoelectric system from simple perovskites, which evidence dielectric and magnetic behaviors as $SrTiO_3$ and $SrMnO_3$, respectively [5,6], we propose the new Sr_2TiMnO_6 (STMO) manganite-like material. In this paper we present synthesis and characterization of STMO. We found that this material belongs to the complex perovskite family. Magnetic measurements show the magnetic ordering feature and polarization hysteresis curves reveal the ferroelectric character of STMO.

2. Experimental

Samples were synthesized by means of solid state reaction recipe. The precursor powders SrO, TiO_2 and MnO_2 (Aldrich 99.9%) were stoichiometrically mixed according to the chemical formula Sr_2TiMnO_6. Mixture was ground to form a pellet and annealed at 1250 °C for 12 h. The samples were then regrinded, repelletized and sintered at 1250 °C for 24 h and 1350 °C for 24 h. X-ray diffraction (XRD) experiment was performed by means of

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a PW1710 diffractometer with $\lambda_{CuK\alpha}$=1.54064 Å. Rietveld refinement of diffraction pattern was made by the GSAS program [7]. Zero field cooling (ZFC) and field cooling (FC) measurements of magnetization as a function of temperature were carried out by using an MPMS Quantum Design SQUID. Electric polarization curves were measured by means of a radiant ferroelectric tester, which include a ± 10 kV source for experiments in bulk samples.

3. Results and discussion

The analysis of XRD pattern shown in Fig. 1 reveals the presence of characteristic peaks of complex perovskite systems.

In Fig. 1, crosses represent the experimental data and lines correspond to simulated pattern by means of GSAS code. Rietveld refinement permitted to establish that this material crystallizes in a tetragonal double perovskite with space group I/4m (#87) and lattice parameters $a = 5.4858$ Å and $c = 7.7518$ Å. These results are 99.78% in agreement with the theoretical values obtained from the structure prediction diagnostic software SPuDS [8], which predicts the lattice constants $a = 5.4702$ Å and $c = 7.7361$ Å. Positions of atoms in the structure are shown in Table 1.

The magnetic properties of STMO have been investigated by measuring the DC magnetization in the temperature range 5–300 K and at an applied magnetic field of 0.2 T. Fig. 2 shows the temperature dependence of the DC magnetization as a function of temperature for STMO when measured by using the ZFC and FC recipes.

The temperature derivative $d\chi/dT$ is shown in the inset of Fig. 2. We use the minimum observed in $d\chi/dT$ as a function of temperature to determine the critical temperature $T_C = 44.8$ K. Particularly interesting is the result of irreversibility observed for the ZFC and FC curves. This separation of ZFC and FC magnetization as a function of temperature is a characteristic of frustrated ferromagnetic systems [9]. Hysteresis curve of Fig. 3 confirms the ferromagnetic behavior with a magnetization saturation value of 0.2 emu/cm^3. From this result and the unitary

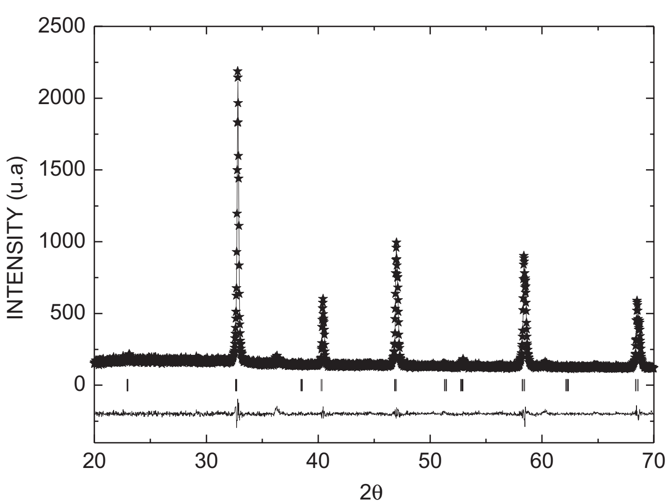

Fig. 1. Characteristic XRD pattern for the complex perovskite STMO.

Table 1
Atomic positions for STMO obtained from Rietveld analysis, which are 99% in concordance with the SPuDS predictions [7]

Atom	Site	*x*	*y*	*z*
Sr^{+2}	4d	0.000	0.500	0.250
Ti^{+4}	2a	0.000	0.000	0.000
Mn^{+4}	2b	0.500	0.500	0.000
O^{-2}	4e	0.000	0.000	0.2504
O^{-2}	8h	0.2570	0.2429	0.000

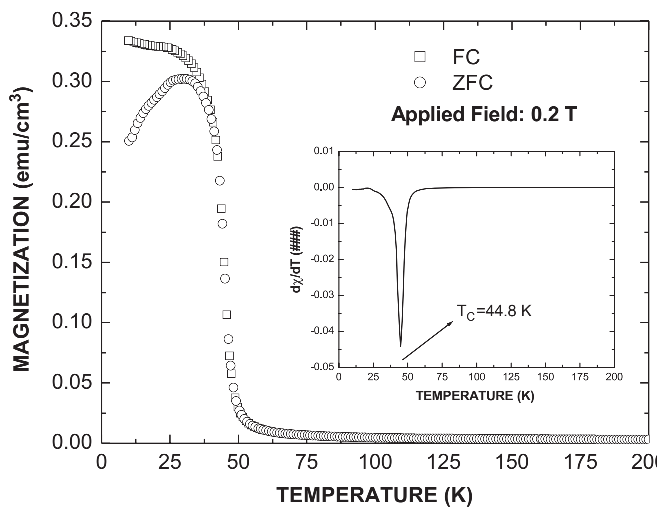

Fig. 2. Magnetic behavior of STMO obtained from measurements of magnetization as a function of temperature. Inset shows the temperature derivative $d\chi/dT$ for the FC recipe.

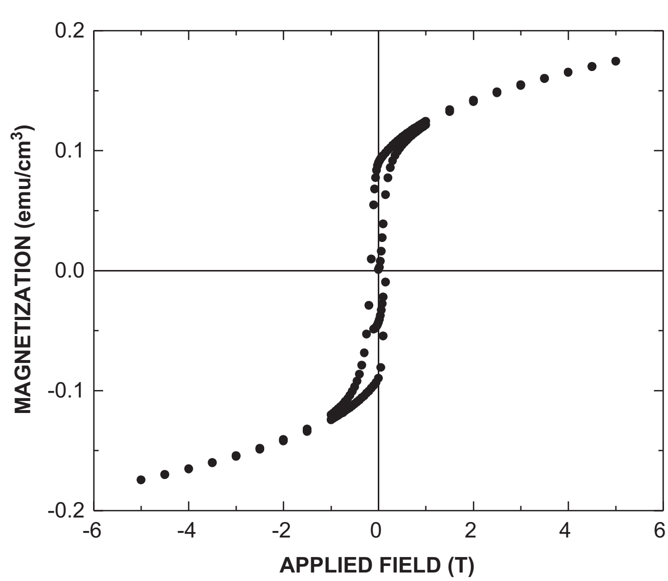

Fig. 3. Hysteretic ferromagnetic behavior of magnetization as a function of applied magnetic field for STMO.

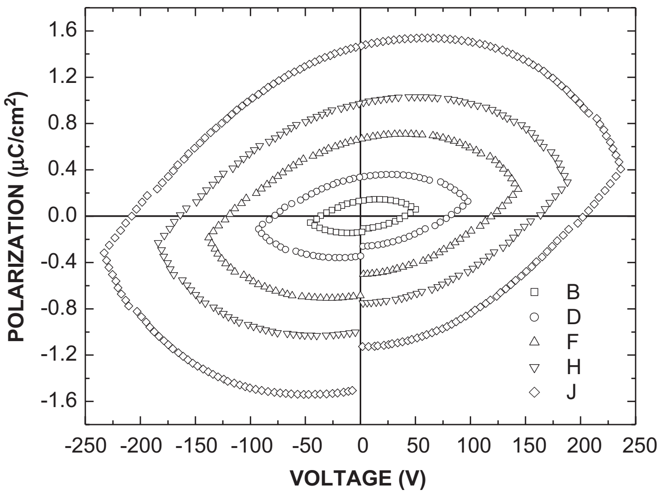

Fig. 4. Hysteretic ferroelectric feature of polarization as a function of applied voltage for STMO on several applied voltages.

crystallographic cell, we calculated the effective magnetic moment of material to be 5.0 μ_B.

Measurements of polarization as a function of applied voltage were performed in order to establish the multiferroic behavior of STMO material. Fig. 4 shows hysteresis loops of the material in a capacitor configuration, under several applied voltages, which reveal the characteristic ferroelectric response of STMO.

Due to the bulk characteristic of samples, at up the applied voltage in Fig. 4 we do not observe a well-saturated polarization. On the other hand, the evidences of the experiments show the possible occurrence of a non-conventional polarization effect, which is observed as an anomaly in the hysteretic behavior shown in Fig. 4. For hysteresis curves of polarization as a function of applied voltage a small asymmetry is systematically evidenced. Particularly, it is observed that the system is smoothly positively polarized.

4. Conclusions

Synthesis and structural characterization of new Sr_2TiMnO_6 manganite-like material were performed. Rietveld analyses reveal that this material crystallizes in a tetragonal complex perovskite which belongs to the space group I/4m. Measurements of magnetization showed a paramagnetic–ferromagnetic transition with the presence of a typical irreversibility of magnetic ordered frustrated materials. Saturation of magnetization in the ferromagnetic hysteresis curve permitted to determine an effective magnetic moment of 5.0 μ_B. Magnetoelectric behavior of this system was examined from magnetization and polarization hysteretic curves.

Acknowledgments

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