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Synthesis and magnetic property of $DyMnO_3$ nanoparticles in mesoporous silica

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Introduction

The magnetic nanoparticles show many curious size effects due to finite size effect and changes of surface state and crystal structure etc. Multiferroic materials $RMnO_3$ (R: rare earth) have strong coupling between magnetism and ferroelectricity. We are interested in the physical property for $DyMnO_3$ nanoparticles. $DyMnO_3$ exhibits the antiferromagnetic transition among the Mn spins at $T_N \approx 40$ K. The ferroelectricity is attributed to lattice modulation accompanied by the antiferromagnetic order. [1] Mesoporous silica SBA-15 was used as a template to equalize the particle size in fabrication of $DyMnO_3$ nanoparticles. We report the synthesis of the $DyMnO_3$ nanoparticles in the pores of mesoporous silica SBA-15 and their magnetic property.

Experimental

The $DyMnO_3$ nanoparticles were synthesized in the one-dimensional pores of SBA-15 with a diameter of about 8 nm by soaking the SBA-15 in a stoichiometric aqueous solution of $Dy(CH_3COO)_3{\cdot}4H_2O$ and $Mn(CH_3COO)_2{\cdot}4H_2O$. And then, the soaked sample were dried and calcinated in an oxygen atmosphere. The powder XRD measurements for the $DyMnO_3$ nanoparticles using a synchrotron radiation X-ray diffractometer at BL-8B of Photon Factory. The incident X-ray energy was 18 keV. The magnetic properties of the $DyMnO_3$ nanoparticles were measured using a SQUID magnetometer (Quantum Design MPMS-5S).

Experimental results

Figure 1 shows the background subtracted powder XRD pattern for the $DyMnO_3$ nanoparticles in SBA-15 at room temperature. The diffraction pattern exhibited some Bragg peaks, which indicated presence of $DyMnO_3$ and impurity phases, Dy_2O_3 and Mn_7SiO_{12}, denoted by asterisk in Fig. 1. The average particle size of the $DyMnO_3$ nanoparticles was estimated to be about 9nm by the use of the Scherrer's equation for some Bragg peaks. The estimated particle size is consistent with the diameter of one-dimensional pore of SBA-15. The XRD pattern indicated successful synthesis of the $DyMnO_3$ nanoparticles with diameter of about 9nm in SBA-15.

Figure 2 shows the temperature dependence of the dc magnetic susceptibility for the $DyMnO_3$ nanoparticle in the pores of SBA-15. The appearance of irreversibility between field-cooled (FC) and zero-field-cooled (ZFC) susceptibilities below 25 K was attributed to blocking phenomena due to the superparamagnetism, since the non-linear susceptibility did not exhibit a critical divergence at the temperature where hysteresis started between the FC and the ZFC susceptibility. The increase in both the FC and the ZFC susceptibility below 10 K were caused by the magnetic ordering of Dy moment ($T_N^{Dy} = 9$K) [2] in $DyMnO_3$ and the presence of paramagnetic compound Dy_2O_3. The magnetization curves exhibited hysteresis loop below blocking temperature and were reproduced by Langevin function. We observed the superparamagnetic behavior for $DyMnO_3$ nanoparticles with diameter of about 9 nm.

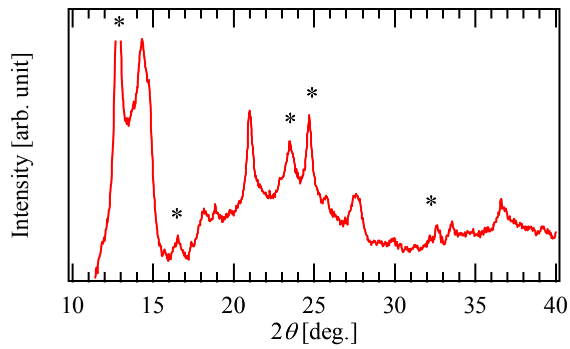

Fig. 1. Powder XRD pattern for $DyMnO_3$ nanoparticles in SBA-15. The asterisk symbols denote the Bragg peaks of impurity phase.

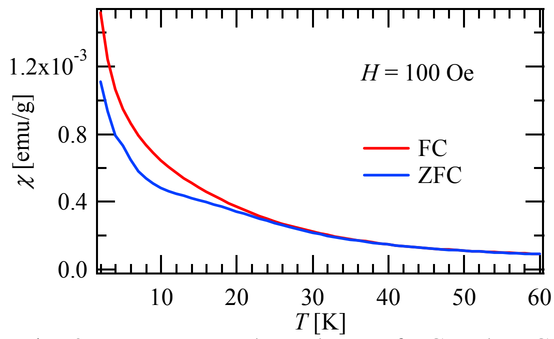

Fig. 2. Temperature dependence of FC and ZFC magnetic susceptibility for $DyMnO_3$ nanoparticle in SBA-15 at $H = 100$ Oe.

References

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