

Anisotropic strain effects on $\text{LaMnO}_{3+\delta}$ nanoparticles embedded in mesoporous silicaTakayuki Tajiri^{1,*}, Seiya Saisho², Yuki Komorida², Masaki Mito², and Hiroyuki Deguchi²¹Faculty of Science, Fukuoka University, Fukuoka 814-0180, Japan²Faculty of Engineering, Kyushu Institute of Technology, Kitakyushu 804-8550, Japan

1 Introduction

The influence of anisotropic strain, which causes distortion of particle shape, on the physical properties of nanoparticles is of particular interest. The changes in the surface state and crystal structure due to anisotropic stress are different from those due to hydrostatic pressure. These changes due to anisotropic stress lead to changes in physical properties of the material, especially in the case of nanometer-sized materials. $\text{LaMnO}_{3+\delta}$ (LMO) nanoparticles with diameters of about 8 nm embedded in SBA-15 showed novel size effects such as coexistence of two non-interacting magnetic components [1]. In this study, we attempted to apply anisotropic stress to LMO nanoparticles embedded in one-dimensional pores of mesoporous silica SBA-15 by applying pressure to SBA-15/nanoparticle composites [2]. The LMO nanoparticles were subjected to anisotropic stress by the silica walls separating the one-dimensional pores.

2 Experiment

The average particle size of the LMO nanoparticles at ambient pressure was about 10 nm. Powder X-ray diffraction (XRD) measurements for the LMO nanoparticles were performed under high pressure at room temperature. SBA-15 containing the LMO nanoparticles was pressurized using a diamond anvil cell. The ac magnetic susceptibility of the LMO nanoparticles under high pressure was measured using a SQUID magnetometer. A piston-cylinder type of pressure cell made of CuBe was used to generate pressure.

3 Results and Discussion

Powder XRD patterns showed that the LMO nanoparticles maintained the rhombohedral structure (space group: $R\bar{3}c$) up to 15.3 kbar. Both the evaluated lattice parameters a and c decreased up to 7.7 kbar and did not exhibit any noticeable change above that pressure, as shown in inset of Fig. 1. The pressure dependence of the lattice parameters indicates that the LMO lattice was compressed in an anisotropic manner; the compression ratio in the direction of c axis was about 2.5 times greater than that in the direction of a -axis. In contrast, the $\text{La}_{0.7}\text{Sr}_{0.3}\text{MnO}_3$ bulk crystals with the rhombohedral symmetry exhibited linear isotropic compression of the lattice under hydrostatic pressure [3]. Figure 1 shows the pressure dependence of the lattice strain in the LMO nanoparticles. The lattice strain in LMO nanoparticles was estimated from the slope of the straight line in the Williamson-Hall plot. The lattice strain increased monotonically up to 7.7 kbar. Above 7.7 kbar, the lattice

strain was saturated. The pressure dependence of the lattice strain was qualitatively similar to that of the lattice constants.

As pressure increased, both the magnetic transition temperatures, T_C and T_N , for the LMO nanoparticles increased monotonically and saturated above 4.2 kbar. All of magnetic transition temperatures, lattice constants, and strain saturated in similar pressure ranges. These results indicated that the increase in the magnetic transition temperatures was related to the changes in the crystal structure. It was considered that the anisotropic compression of the crystal structure facilitated an increase in the Mn-O-Mn bond angle in the LMO nanoparticles. As a result, the change in the crystal structure under anisotropic stress induced enhancement of the exchange interaction, resulting in the increase in the magnetic transition temperatures.

These experimental results indicated that successful application of anisotropic stress. It was considered that the LMO nanoparticles in the one-dimensional pores of SBA-15 were subjected to anisotropic strain, so that the distortion of the particle shape, the changes in the crystal structure, and the changes in magnetic and electronic states of the nanoparticles were induced.

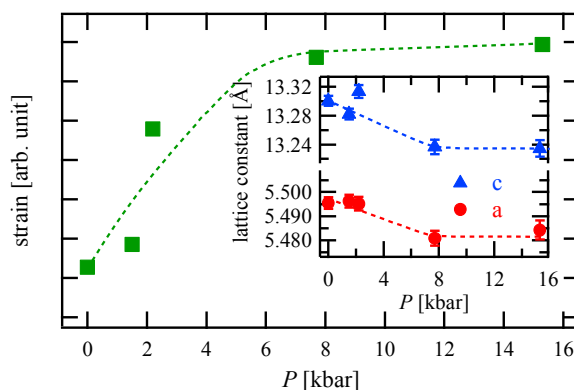


Fig. 1: Pressure dependence of lattice strain in LMO nanoparticles in SBA-15. Inset shows pressure dependence of lattice constants a and c for LMO nanoparticles.

References

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