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Effects of a strong gravity on $YMnO_3$ single crystal

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1 Introduction

Hexagonal manganites $RMnO_3$ (R is a rare earth element) crystallize in a hexagonal structure (space group: $P6_3cm$) if the ionic radius of R is small (R=Ho-Lu, Y, and Sc). These compounds have attracted attention because they exhibit multiferroic effects. The crystal and magnetic structures of these compounds have been investigated to assess their possible applications in electronics.

Similar to magnetic and electric fields, gravity is a field state variable that acts directly on atoms in materials through a body force, whereas pressure and temperature are thermodynamic variables that affect atoms statistically. Unique uniaxially distorted crystalline state can induce structural changes in compounds other than those caused by high pressure and high temperature, thereby allowing the formation of a unique metastable phase. In the present study, we investigated the detailed relationships between the changes in the structure and magnetic properties of the YMnO3 single crystal quenched in a strong gravitational field [1].

2 Experiment

A single crystal of YMnO3 was grown in a desktop-type furnace using the floating-zone method. The direction of the gravitational field was perpendicular to the Si_3N_4 plate and parallel to the [0001] plane of the sample. At a rotational velocity of 140000rpm, the gravitational force on the sample was 0.78×10^6G in a vacuum. The rotor was heated to 400°C using a hollow carbon cylinder, which was heated by a high-frequency heating system. Toward the end of this procedure, the sample was quenched to room temperature and the rotation was stopped within about 5min.

Crystallographic data were determined a four-circle diffractometer using synchrotron radiation at beamline BL-10A of PF, KEK. The structure was solved by direct methods and refined using a full-matrix least squares procedure in the SHELXL refinement package using least-squares minimization.

3 Results and Discussion

Under strong gravitational fields, the unique uniaxially distorted crystalline state induces structural changes in compounds other than those caused by high pressure and high temperature [1]. We determined the changes in the crystalline structure and physical properties of the metastable $YMnO_3$ quenched in the strong gravitational field (Fig. 1). According to four-circle single-crystal X-ray diffraction data, the structural analyses indicated changes in the inequivalent nearest-neighbor Mn-Mn and Mn-O bond distances, thereby demonstrating that trimerization distortion occurred in the ab plane under the strong gravitational field (Fig.2). Raman spectroscopy measurements showed that the Raman peaks for the gravity sample included a new Raman line at $178cm^{-1}$, which has never been reported in previous experimental studies. Magnetic measurements indicated that there were changes in the magnetic anisotropy, which were explained by changes in the spin–orbit interaction due to lattice distortion.

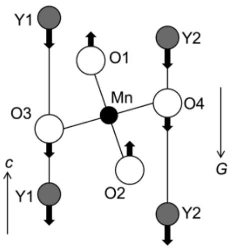

Fig. 1: Schematic showing the displacement of the atoms along the c-axis after the strong-gravity experiments [1].

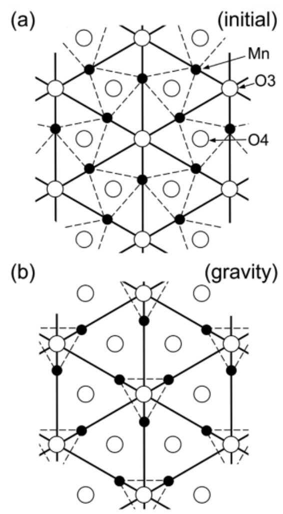

Fig. 2: Schematics illustrating the formation of the Mn-trimer in the ab-plane for the initial (a) and gravity (b) samples. The Mn trimers in the initial sample were connected with each other organically over the ab-plane, whereas each Mn trimer was isolated in the gravity sample [1].

References

[1] M. Tokuda *et al.*, J. Phys. Chem. Solids, **129**, 172 (2019) https://doi.org/10.1016/j.jpcs.2018.12.023

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