

## Magnetic Field Induced Phase Transition in Distorted Perovskite $\text{Eu}_{0.6}\text{Sr}_{0.4}\text{MnO}_3$

A distorted perovskite  $\text{Eu}_{0.6}\text{Sr}_{0.4}\text{MnO}_3$  shows a magnetic field-induced insulator-to-metal (IM) transition at approximately below 75 K [1,2]. The magnetic field-induced change in resistivity ( $\rho$ ) exceeds 6 figures ( $10^6$ ) at 12 K. It also accompanies a transition from a low magnetization phase ( $\sigma = 25$  emu/g) to a high magnetization phase (85 emu/g). The transition fields are 20 kOe at 5 K and 10 kOe at 20 K. Once it takes places, the induced metallic and ferromagnetic states remain stable even in the absence of a magnetic field. There is no evidence in the  $\rho - T$  curve that charge ordering occurs. The electronic state of Eu ions remains unchanged through the transition [3]. The transition also accompanies a magnetostriction of  $-4 \times 10^{-4}$  and the application of a pressure also induces the IM transition [4]. This suggests that the transition also accompanies a structural phase transition. Thus, in this investigation, we measured the powder X-ray diffraction in a magnetic field and discuss whether the transition accompanies a structural phase transition. Synchrotron X-ray radiation at beamlines **BL39XU** ( $\lambda = 0.8231$  Å) and **BL46XU** ( $\lambda = 0.56355$  Å) was used for the diffraction measurements. The measurements were conducted with magnetic fields up to 20 kOe, perpendicular to the scattering plane [5].

The crystal structure is orthorhombic ( $Pnma$ ) with lattice constants  $a = 5.4463(3)$  Å,  $b = 7.6669(4)$  Å and  $c = 5.4329(3)$  Å at room temperature. Mn-O-Mn angles are about  $160^\circ$ . The lattice constants decrease monotonically with decreasing temperature. No superstructure was detected down to 20 K, which also indicates the absence of charge ordering. At 20 K, the full powder pattern of the insulator phase ( $H = 0$ ) and that of the metal phase ( $H = 20$  kOe) are both well analyzed to reveal a  $Pnma$  space group. Therefore, no distinct phase transition is realized through the IM transition.

In Fig. 1, 404 / 080 diffraction peaks at 20 K are shown for various applied magnetic fields ( $H$ ) after cooled without magnetic field (ZFC). It is seen that with increasing  $H$ , both peaks shift toward low  $2\theta$  angle and that the peak intensities increase drastically for  $H > 10$  kOe. In Fig. 2, the lattice constant  $b$ , determined from the 080 peak position, is plotted against  $H$ . It increases with increasing  $H$ , showing a jump at approximately 10 kOe where IM transition occurs. The jump  $\Delta b/b$  is about  $4.3 \times 10^{-4}$ , whose magnitude is comparable to that observed in a magnetostriction measurement [4]. After the transition,  $b$  decreases with decreasing  $H$ , showing no jump this time, and reaches a value different

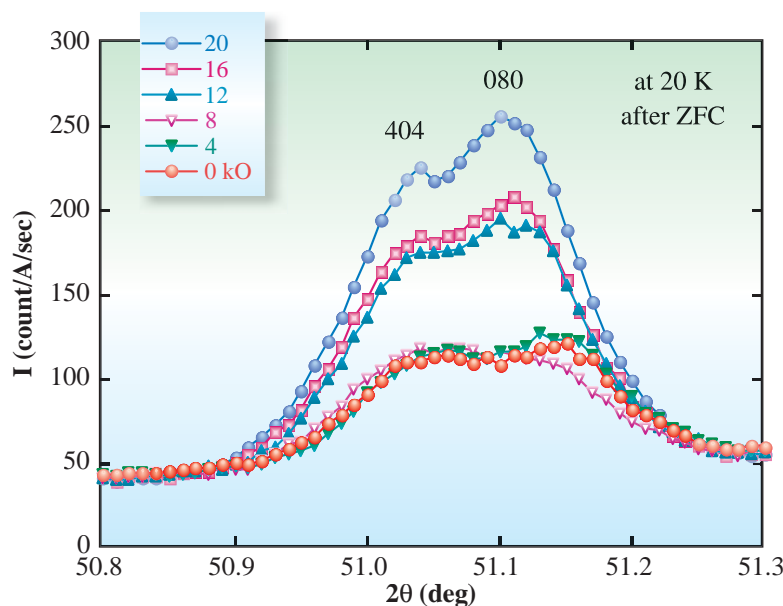


Fig. 1. 404 / 080 peaks at 20 K in various applied magnetic fields after the ZFC process ( $\lambda = 0.8231$  Å).

from the initial one at  $H = 0$ . This is consistent with the  $H$  dependences of magnetoresistance and magnetization, and is suggestive of some kind of phase transition.

Here, we consider the change in peak intensity against  $H$ . In addition to 404 and 080 peaks, the intensities of 400, 004, 440, and 044 peaks increase through the IM transition. On the other hand those of 511 and 115 peaks decrease. These intensity changes represent the displacement of atoms. Taking the structural factors into account, we can derive information on the displacement of atoms through the IM transition. One simple explanation for all these intensity changes is the displacement of oxygen toward O1 (0.5, 0.25, 0) and O2 (0.25, 0, -0.25). The resultant displacement corresponds to the rotation of  $\text{MnO}_6$  octahedrons to increase the Mn-O-Mn angle toward  $180^\circ$ . Such scheme is illustrated in Fig. 3. This structural change leads to a gain of the electron transfer energy in the double exchange mechanism and thus stabilizes the metallic and ferromagnetic states.

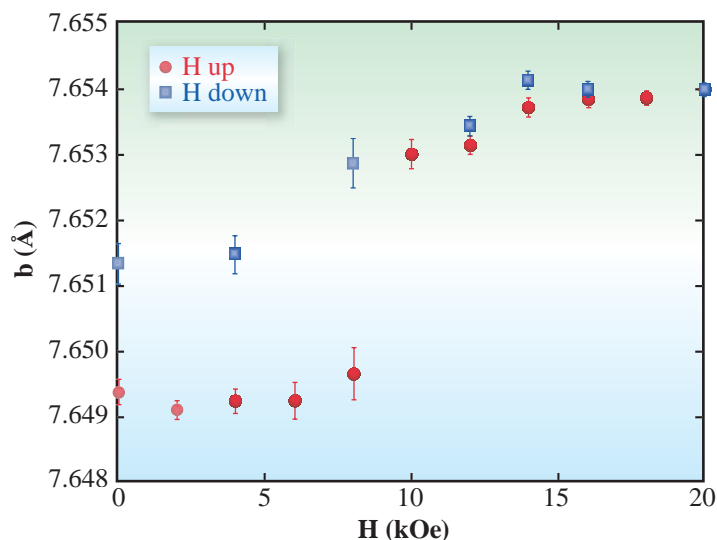


Fig. 2. Dependence of  $b$  on  $H$ .

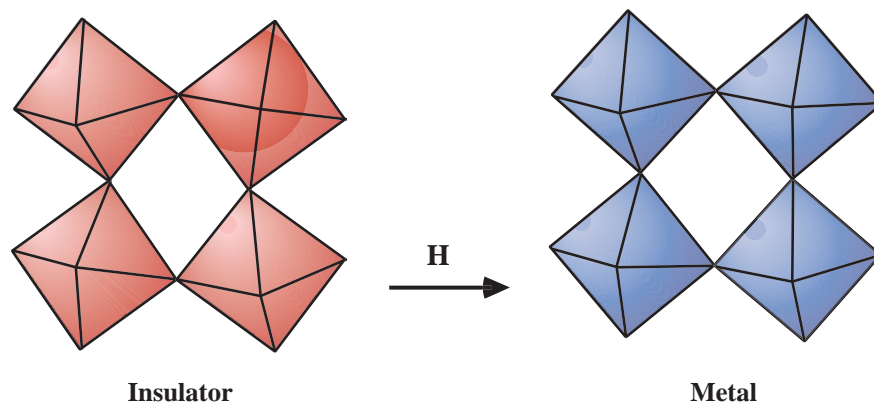


Fig. 3. Rotation of  $\text{MnO}_6$  octahedrons through the IM transition.

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## References

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