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Measurement System of X-ray Diffraction in Strong Magnetic Fields

T. ARIMA[1*], D. OKUYAMA[2], T. MATSUMURA[2], Y. MURAKAMI[2],
T. KAKIUCHI[3], H. SAGAYAMA[1,3], H. SAWA[3]
[1]IMRAM, Tohoku Univ., Sendai 980-8577, Japan
[2]Dept. Phys., Tohoku Univ., Sendai 980-8578, Japan
[3]KEK-PF, Tsukuba, Ibaraki 305-0801, Japan

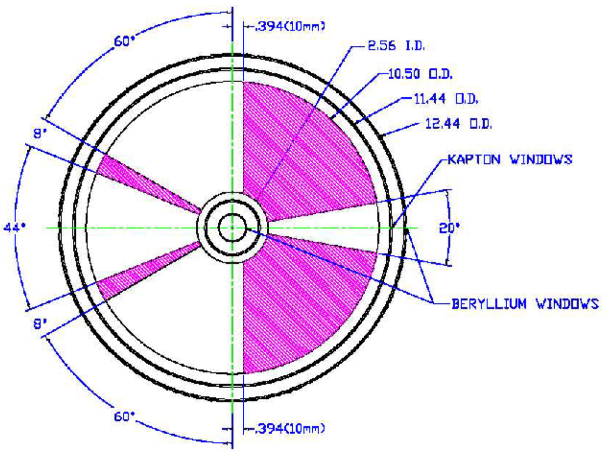
Introduction

Magnetic-field-induced phenomena such as colossal magnetoresistance (CMR) or giant magnetoelectric effects (GME) have recently stimulated interest of many scientists.[1,2] These phenomena are closely related to some order-disorder transition in spin, orbital, and charge degrees of freedom. Some new methods to probe the ordering were developed at Photon Factory. For example, Murakami et al. have first pointed out that x-ray scattering through anomalous tensor susceptibility (ATS) in the CMR-related manganite compounds is attributed to orbital ordering.[3]

In 2005, we fabricated a measurement system of synchrotron x-ray diffraction in magnetic fields to extend the activity on correlated electron systems at Photon Factory.

Specification of the System

A cryostat equipped with an 8-Tesla superconducting magnet (Cryomagnetics, Inc.) is mounted on a multi-circle diffractometer (Huber Co. Ltd.) with a horizontal scattering plane. Magnetic fields are applied vertical, i.e., perpendicular to the scattering vector. Beryllium windows are coordinated on the cryostat as shown in Fig. 1. One can collect scattering data with an angle less than 120 degree can be measured. Temperature of a sample mounted on a top-loaded rod can be controlled between 1.5 and 300 K. We found that scintillation counters are sensitive to high magnetic fields. Therefore we use a silicon PIN x-ray detector (Amptek Inc.) to avoid the magnetic-field effect.



In the present system, orientation of single crystalline sample should be prior to the experiment because the cryostat can be tilt by less than 3 degrees. We now design a new sample rod geared with a sample rotator.

Ongoing Studies

We start the following studies by using the measurement system. The results will be published in near future.

Magnetoelectric Perovskite Manganites

$TbMnO_3$ undergoes a transition from ferroelectric to paraelectric phase with the application of magnetic field along the *a* axis. We have found that superlattice reflections with a modulation vector (0 Q 0) suddenly disappear upon the transition. This result implies that the transition should result from the change of antiferromagnetic spin arrangement from the long-period type to the layered type.

With a magnetic field along the *b* axis, the ferroelectric polarization in $TbMnO_3$ flops by 90 degrees, accompanied by the incommensurate-commensurate transition of antiferromagnetism and superlattice magnetostriction. In contrast, almost no change with polarization flop was found in superlattice modulation vector in the cases of $DyMnO_3$ and $(Eu,Y)MnO_3$.

Magnetoresistive Perovskite Manganite Films

Change in structure of $Nd_{0.5}Sr_{0.5}MnO_3$ film on $SrTiO_3$ (110) substrate upon the ferromagnetic transition was investigated. With warming the sample in lower magnetic fields than 3 T, a change in lattice constants is observed at about 10 K lower than the metal-insulator transition temperature. The intermediate phase might be the so-called A-type layered antiferromagnetic phase. In higher magnetic fields, the lattice constants change simultaneously with the metal-insulator transition.

References

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* arima@tagen.tohoku.ac.jp