Synchrotron X-ray Diffraction Measurements in High Magnetic Fields and Low Temperatures

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With the use of high intensity X-rays from the SPring-8, X-ray diffraction by magnetic materials are now routinely measured at the beamline BL19LXU. It is then natural to extend the measurement to higher magnetic fields and to lower temperatures. We have constructed an X-ray diffractometer equipped with a 15 T superconducting magnet in conjunction with a dilution refrigerator. In this presentation, I will report on our recent results of X-ray magnetic and charge scattering measurements on magnetic materials obtained in high magnetic fields and/or at very low temperatures.

1) Observation of the spin-flop transition in MnF_2 by X-rays

It is well established that the intensity of neutrons diffracted by a magnetic material depends on the angle the magnetic moment in the sample makes with the scattering vector. We have studied the dependence of X-ray magnetic diffraction intensity on the scattering vector. For this purpose, we measured the spin-flop transition in a uniaxial antiferromagnet MnF_2. We found that the magnetic (3, 0, 0) Bragg intensity decreased steeply at about 9.3 T at which the spin-flop transition has been observed from bulk measurements.

2) X-ray diffraction measurements in the high field phase of a spin-Peierls compound $CuGeO_3$

We have measured the temperature dependence of the lattice incommensurability, δ in the high field phase of $CuGeO_3$ at fixed fields. At 12.6 T, slightly above the critical field from the commensurate to incommensurate phases, we observed that δ became small with increasing temperature, in accordance with the observation reported before. In contrast, at 15 T, δ is almost independent of temperature. This observation shows that strong magnetic fields suppress the thermal fluctuation of the incommensurate state.

3) Observation of lattice instability at the field induced phase transition of the spin gapped compound $Cu_2(C_5H_{12}N_2)_2Cl_4$

The ground state of the title compound is a singlet and the material shows a field induced magnetic ordering at low temperatures below about 0.8 K. We have measured the field dependence of the lattice constants in this compound at about 40 mK and found the lattice constant showed a jump at about 7.3 T. This observation is consistent with a theoretical prediction of the lattice instability associated with the field induced phase transition in a quantum antiferromagnet.

The results reported here have been obtained in collaboration with C. Berthier, T. Bizen, S. Goto, M. Hagiwara, T. Hara, I. Harada, T. Ishikawa, S. Kimura, H. Kitamura, J. E. Lorenzo, S. W. Lovesey, M. Matsuda, T. Matsushita, H. Mayaffre, H.-J. Mikeska, T. Nakamura, Y. Narumi, Y. Nishiyama, H. Ohashi, T. Ohata, S. Shimomura, Y. Tabata, K. Takeshita, K. Tamasaku, T. Tanaka, Y. Tanaka, M. Yabashi and I. Yamada.