Inelastic neutron scattering in the impurity-induced ferroelectric phase of $CuFe_{1-y}Ga_yO_2$

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Since the discovery of the magnetic-field-induced ferroelectric phase transition in $CuFeO_2$,[1] the magnetoelectric coupling in this compound has attracted considerable attention. Although the static features, such as magnetic structure and ferroelectric polarization, in this system have been relatively well understood, the magnetic excitation has not been fully understood so far.

This time, in order to determine the spin wave dispersion relation of the nonmagnetic impurity induced ferroelectric incommensurate (FEIC) phase in $CuFe_{1-y}Ga_yO_2$, we have performed the inelastic neutron scattering measurements on $CuFe_{0.965}Ga_{0.035}O_2$. Unlike the FEIC phase of the Al-doped sample with spatially distributed magnetic domains with two different wave numbers, the FEIC phase of the Ga-doped sample is characterized by a single wave number.[2]

The experiment was carried out with the cold neutron triple-axis spectrometer HER installed at C1-1 beam port in the guide hall of JRR-3. The single crystal sample is of the mass 4.8 g. Constant $E_f(= 3$ meV) mode was used. To cut off the higher order contamination, the Be filter was put back of the sample.

As shown in Fig. 1, we obtained the contour map of the neutron scattering intensity corresponding to the dynamic structure factor $S(\mathbf{Q},\omega)$ along the $[H,H,3/2]$ direction in the FEIC phase of $CuFe_{0.965}Ga_{0.035}O_2$. In the previous neutron diffraction measurements[2], the Bragg reflections at $(q\ q\ \frac{3}{2})$ and $(\frac{1}{2}-q\ \frac{1}{2}-q\ \frac{3}{2})$ with $q = 0.203$ were observed. The lowest energy spin wave branch starts from the two reflection points, where the energy gap of the branch is smaller than 0.2 meV. We confirmed that the spin wave with energy gap in the 4-sublattice (4SL) phase of pure system of $CuFeO_2$[3, 4] is soften and the energy gap goes to zero by a small amount of nonmagnetic impurity.

The relatively complex dispersion relation has not been solved completely at the present stage. There are two types of model for geometric pattern of the exchange interaction. One is a simple triangular lattice model that is considered up to third nearest neighbor exchange interactions, which was applied to the pure $CuFeO_2$ by the other group.[4] However, the lattice distortion occurs in both the 4SL and the FEIC phases. We therefore expect that the scalene triangular lattice model, where the nearest neighbor interactions splits into the three different interactions as the result of the lattice distortion, could explain the dispersion relation.

References

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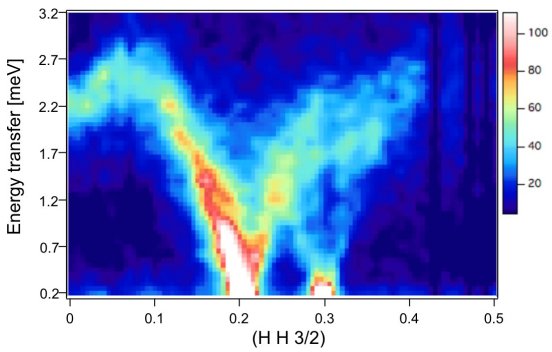

Fig. 1. The spin wave dispersion relation along the $[H,H,3/2]$ direction in the ferroelectric incommensurate phase of $CuFe_{0.965}Ga_{0.035}O_2$.