Electronic state in novel superconductor $CeCoIn_5$ studied by observation of the vortex state

H. Kawano-Furukawa[1], S. Ohira-Kawamura[2], S. Konno[1], R. Nagatomo[3], H. Shishido[4], T. Shibauchi[4], Y. Matsuda[4,5]

[1]*Graduate School of Humanities and Sciences, Ochanomizu University*
[2]*Academic and Information Board, Ochanomizu University*
[3]*Department of Physics, Ochanomizu University*
[4]*Department of Physics, Kyoto University*
[5]*ISSP, University of Tokyo*

$CeCoIn_5$ is a new heavy fermion superconductor with quasi two-dimensional electronic structure and the superconducting transition temperature $T_c = 2.3$ K. The vortex state of this system has attracted a great deal of attention, because some interesting phenomena have been reported. For instance, a possible FFLO state has been suggested in the low-T/high-H corner of the H-T phase diagram[1]. Recently we performed a SANS experiment on this system in the perpendicular field ($H \parallel c$), and found that the square flux line lattice (FLL) structure which was observed above 1 T exhibited reorganization to a triangular one above 4 T and that the internal field inside the vortex cores was unexpectedly enhanced by the external field[2]. In order to investigate its FLL structure of $CeCoIn_5$ in $H \parallel a$, we carried out a SANS experiment on this material.

The measurement was carried out at the C1-2 spectrometer (SANS-U). Neutrons with wavelength of 7.08 Åwere used, and the PSD was set at the 12 or 16 m position from the sample. The single crystal samples (the average size of $3 \times 0.5 \times 0.5$ mm^3) were aligned to cover the $\sim 8 \times 8$ mm^2 area so that the a axis is parallel to the neutron beam and the c axis is parallel to the vertical direction. A ^{4}He cryostat with a 3 T horizontal magnet was used, and the sample was cooled down to 1.6 K. The magnetic field was applied parallel to the a axis and the neutron beam.

The measurements were carried out at 0.1 T and 0.2 T. The data were collected at 1.6 K ($T < T_c$), and the background data collected at 3.5 K ($T > T_c$) were subtracted. We spent 6 hours to collect the data at each temperature. However, no reflections from the FLL were observed. The signal was not detected even in the scattering vector (Q) dependence and the azimuthal angle (θ) dependence of the scattering intensity. We note that, in the case of the measurement for $H \parallel c$, the diffraction spots from the FLL are clearly observed in shorter time.

The $CeCoIn_5$ crystal has the tetragonal symmetry (space group $P4/mmm$), and the symmetry axis corresponds to the crystallographic c axis. When the magnetic field is applied parallel to the a axis (equivalent for the b axis), the magnetic penetration depths for the b and c directions, λ_{ab} and λ_c, are expected to be significantly different (λ_{ab} is several times longer than λ_c). In this case, the supercurrent is expected to be no longer circular but anisotropic. Namely, the FLL structure should be distorted. On the other hand, the sample angle ω was calculated assuming isotropic triangular or square FLL. Therefore, we currently expect that the reason why the reflections were not observed in the present study is that the chosen sample angle ω did not satisfy the Bragg condition.

[1] See, for example, K. Kumagai et al., Phys. Rev. Lett. 97 (2006) 277002.

[2] S. Ohira-Kawamura et al., J. Phys. Soc. Jpn. (2008) in press.