Flux Line Lattice Symmetry in MgB$_2$-type Superconductor CaAlSi probed by Small Angle Neutron Scattering

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Since the flux line lattice (FLL) configuration can be dominated by the Fermi surface property and underlying crystal symmetry, investigations of FLL state play an important role to understand the superconducting mechanism. In this work, we have focused on the superconductivity in a MgB$_2$-type superconductor CaAlSi (CAS).

According to the recent report [1], the CAS possesses two types of multi-stacked crystal structures, in which a clear five-layered (5H-CAS) or six-layered (6H-CAS) superlattice along the $c$-axis was observed. On the other hand, we first fabricated a no superstructured CAS (1H-CAS) with AlB$_2$-like structure [2]. In order to clarify the relationship between the crystal symmetry, structure of superconducting order parameter and vortex lattice symmetry in three phases of CAS, we have performed the first small angle neutron scattering (SANS) experiments.

The SANS experiment was conducted by using SANS-U spectrometer installed in JRR-3 at Japan Atomic Energy Agency (JAEA), and single crystal of respective phase with the dimension $7 \times 7 \times 2$ mm$^3$ was used. The mean wavelength of incident neutron beam monochromatized by a mechanical velocity selector was set to $\lambda_n \sim 6.7$ Å with resolution $\Delta \lambda_n/\lambda_n = 10 \%$.

Figure 1 shows the representative SANS diffraction patterns in 6H-CAS (not shown the data of 1H- and 5H-CAS) at 2 K applied fields parallel to the crystalline (a) $c$- and (b) $a$-axes. We found that the hexagonal FLL structure under $H \parallel c$ over the entire temperature/field range was observed in the respective phases in CAS, but that they exhibit a no sign of reorientation with increasing temperature/field as in multi-gaped superconductor MgB$_2$ [3]. Meanwhile, only 6H-CAS shows a distortion with Bragg peaks lying on an ellipse under $H \parallel a$ due to the magnetic penetration depth anisotropy.

Consequently, we obtained an usual FLL phase diagram in 6H-CAS expected for the uniaxial conventional superconductor described by London theory. The further SANS experiments are also needed to determine the comprehensive FLL phase diagram in 5H- and 1H-CAS.

References

Fig. 1. SANS diffraction patterns from the FLL state in 6H-CaAlSi at 2 K applied fields of 1.5 kOe parallel to the crystalline (a) c- and (c) a-axes.