Neutron Depolarization Studies on Magnetic Flux Dynamics in Superconductors(Abstracts of Doctral Dissertations)

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Neutron Depolarization Studies on Magnetic Flux Dynamics in Superconductors

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Abstract

Neutron depolarization measurements were performed on the magnetic flux state trapped in the superconducting single crystals by using TOP polarized neutron spectrometer installed at the pulsed neutron facility at the National Laboratory for High Energy Physics (KEK). We can detect the magnetic flux sensitively by the wavelength dependence of polarization at varying temperature and applied magnetic field. In these measurements the lower critical field and the penetration depth of magnetic flux are readily determined and the phase transition of the flux state against of the temperature is observed.

Chap. I. Introduction
The study of the magnetic flux of type-II superconductor was occurred before high temperature superconductor was find, but from then the study of magnetic flux is needed to do hard and many-sided work because of the existent of the strong anisotropy of high temperature superconductors. Neutron depolarization method using polarized neutron is very simple method, but is very useful and unique experimental method for research of magnetic distribution in magnetic materials. We discuss about the study of magnetic distribution of fluxes pinned in the type-II superconductor using this depolarization method.

Chap. II. Improvement of the polarized neutron spectrometer
These studies were performed by using TOP (Time-of-flight spectrometer with Optical Polarizer) polarized neutron spectrometer. In these studies I improved TOP spectrometer system in the data acquisition system and in the magnet system for the experiment of the magnetic flux in superconductors and improved it to the reflectometer. We have been able to do three kinds of experiments after this improvement, one is small angle scattering experiment, second is depolarization experiment and three is reflection experiment.

Chap. III. Neutron Depolarization Studies on Mixed State of Superconductors
The principle of the neutron depolarization experiments is that the polarization of transmitted neutron beams is related to the Larmor precession of neutron polarization

vector around the magnetic induction in a sample. Neutron depolarization of the wavelength λ dependence senses the magnetic induction of mesoscopic scale inside the bulk material. We have measured single crystalline plate $La_{1.85}Sr_{0.15}CuO_4$ (Tc=36K) and V_3Si (Tc=16.1K) single crystal. The former is the high temperature oxide superconductor and the latter is the A15 typical type-II superconductor. In the zero field cooling (ZFC) process experiment, depolarization appears, once this crystal was passed in the magnetic field above the lower critical field Hc1 after ZFC. The $Hc1(T)$ of $La_{1.85}Sr_{0.15}CuO_4$ single crystal is normal, below Tc the $Hc1(T)$ rise linearly and in low temperature the $Hc1(T)$ shows saturation for each $Hc1//c$-*axis* and $Hc1\perp c$-axis. Fundamentally the $Hc1(T)$ behave the normal BCS theory. We observed the value of $Hc1//c(0)(\approx 230$ Oe$)$ / $Hc1\perp c(0)(\approx 60$ Oe$) \approx 3.8$. Same operation was done to the V_3Si single crystal. The V_3Si dose not have anisotropy $Hc1(0)\approx 1150$ Oe, and have normal behavior. Other group reports unusual results, such as Hc1 of YBaCuO up-turn at low temperature like UP_3 that is d-wave superconductor. However our result shows $La_{1.85}Sr_{0.15}CuO_4$ is normal s-wave superconductor data. In the field cooling (FC) process, the sample was cooled under the magnetic field (FC) and after reaching the desired temperature to measure the polarization, the applied field to induce the flux was removed. In the sample when the FC field becomes larger, the oscillation in polarization becomes visible with changing the periodicity with increasing the FC field. After all, the FC field is larger, the trapped magnetic fluxes more increase. The damping in polarization with respect to λ tells us the fact that the phase of the cosine oscillation in polarization are lost by the spatial distribution of the magnetic flux in the crystal. After all, we can define the penetration depth from the damping factor from the FC=400(Oe) data. The temperature dependence of penetration depth Λ of LaSrCuO, VSi respectively looks like saturation to T=0(K). We attempted to fit the data to the empirical two-fluid relation. The penetration depth at temperature T=0(K) are $\Lambda\perp c$-*axis*(0) =1400(Å), $\Lambda//c$-*axis*(0) =5700(Å) ($La_{1.85}Sr_{0.15}CuO_4$) and 620(Å) (V_3Si). These results suggest that the superconducting energy gap is finite and uniformity and the connection of the electron coupling is s-wave state. The temperature dependence of the magnetization from the trapped magnetic fluxes at high field FC=2000(Oe) show differences between the one from SQUID and the one from depolarization at the hight temperature region, because that fluxes in the sample take the tangled state. However the data of V_3Si do not show that difference. This data is very valuable result for studies of flux phase transition.

Chap. IV. Discussions

Depolarization measurement of polarized cold neutron is very useful to study of flux pinned in high-Tc oxide superconductors. The character of the flux of $La_{1.85}Sr_{0.15}CuO_4$ is similar to one of V_3Si A15 superconductor. However the axis anisotropy and trapped magnetic flux state are differnt between two superconducting materials. This depolarization experiment of wavelength dependence against the magnetic flux in Superconducting is the fiast time in the world, so we may get anothr new viewpoint from this depolarization methid.