Quasiparticle Excitations in the Vortex State of Clean and Dirty superconductors - Specific Heat under Magnetic Fields

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Abstract

The low-temperature specific heat has been measured for the alloy systems of $Y(Ni_{1-x}Pt_x)_2B_2C$ and $Nb_{1-x}Ta_xSe_2$ ($x = 0.0$ and 0.2) under various magnetic fields (H), in order to determine the H dependence of the quasiparticle density of states (DOS) in the vortex state. In the dirty superconductors, $Y(Ni_{0.8}Pt_{0.2})_2B_2C$ and $Nb_{0.8}Ta_{0.2}Se_2$, the coefficient of the T-linear term in specific heat, $\gamma(H)$, increases linearly on H below H_{c2} as $\gamma(H) = \gamma_N H/H_{c2}$, where γ_N is the normal state value. The H-linear behavior has been predicted theoretically for dirty superconductors in a wide field range [Watts-Tobin *et al.*, J. Low Temp. Phys. **17**, 71 (1974)]; The vortex can be viewed as a cylinder of normal electrons with diameter ξ, giving a DOS proportional to $\gamma_N \pi \xi^2$ per vortex line. This value is field independent. Therefore, $\gamma(H)$ is expected to be scaled by the number of vortices and hence by the magnetic field H. Quite surprisingly, we found for the clean superconductors, YNi_2B_2C and $NbSe_2$, that $\gamma(H)$ exhibits a rapid increase at low field range, then gradually approaches the normal state value γ_N. The deviation from the H-linear behavior indicates that the DOS per single vortex depends on H. We discuss the following two possible origins for our observation: (1) Shrinkage of the vortex core radius with increasing H as suggested by recent STM and μSR measurements on $NbSe_2$. (2) Quasiparticles outside the vortex cores as suggested by observations of the dHvA effect in the vortex state.