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Time Dependent Magnetization in the Heavy Fermion Superconductor UBe_{13}

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We have measrued the D.C. magnetization of the heavy fermion superconductor UBe_{13} in both the superconducting and normal state to high magnetic fields. We find an exponential time dependence for the relaxation of the mixed-state magnetization which supports the mechanism of flux jump. τ is both temperature and field dependent and UBe_{13} behaves differently from similar experiments in conventional type II superconductors in this respect. Other substantial difference between the two include observation of a paramagnetic background and evidence for anisotropy effects in the single crystal of UBe_{13} studied. These results will be discussed in light of recent theoretical and experimental work on heavy fermion systems.

1. INTRODUCTION

Since the discovery of the heavy fermion superconductors $CeCu_2Si_2$, UPt_3 and UBe_{13} the nature of the superconducting state has attracted a great deal of attention [1]. The large value of the electronic specific heat coefficient (γ) suggests a large density of states with a narrow band width at the Fermi energy which is characterized by a large effective mass. The magnetic susceptibility follows a Curie-Weiss law at temperatures above 150K and becomes Pauli-like at lower temperatures. The large specific heat jump at T_c indicates that the f electrons are responsible for the superconductivity. UBe_{13} shows non-BCS behavior in the superconducting state leading to the suggestion of a spin-triplet or odd-parity state. Group theoretical arguments, however, show the possibility of explaining these results with a singlet pairing state [2].

2. EXPERIMENTAL RESULTS

We have measured the DC magnetization of single crystal UBe_{13} in both the superconducting and normal states in high magnetic fields with an in-situ capacitive magnetometer [3]. The capacitance is proportional to the magnetic force on the sample. Typical data are shown in Figure 1.

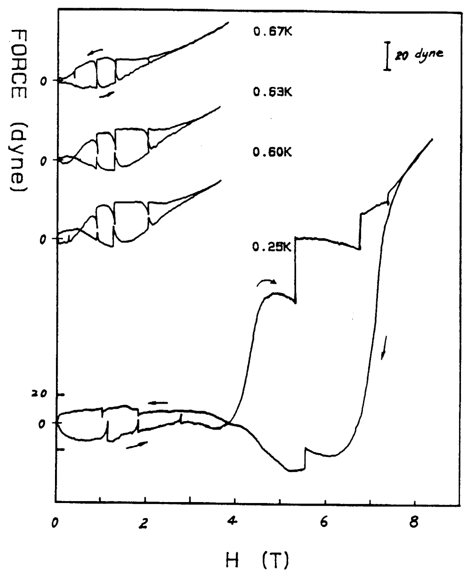

Fig. 1. Force vs. magnetic field for UBe_{13}

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We find a large and time dependent hysteresis in the mixed state. The temporal dependence is exponential with a time constant (τ), as show in Figure 2, which is both temperature and magnetic

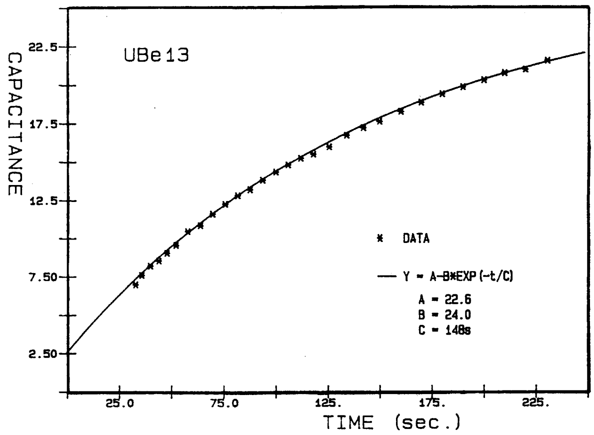

Fig. 2. Relaxation of the capacitance (which is proportional to magnetization) at τ = 0.25K

field dependent. The size of the hysteresis loop increases as the temperature is lowered but disappears as either Hc_2 or T_c is approached. This hysteretic behavior has also been observed in the conventional Type II superconductor $Bi_{.5}Pb_{.5}$ but, in this case, the relaxation times are essentially independent of temperature and magnetic field.

We find two different temporal responses corresponding to regimes above and below the crossover point in the hysteresis loops. Below the crossover the time constants are relatively small and of order 10 to 100 seconds. Above the crossover point the time constants range from 100 to 1000 seconds. Data at two temperatures are shown in Figure 3 and compared to the results from $Bi_{.5}Pb_{.5}$.

We believe that the hysteresis in the mixed state is due to conventional vortex pinning. The time dependence of the hysteretic behavior may be caused by resistance of the flux flow and the finite inductance of the sample [4] in the establishment of the equilibrium mixed state. This time dependence is clearly different from that in a conventional Type II superconductor, possibly reflecting a different mechanism in the establishment of the superconducting mixed state.

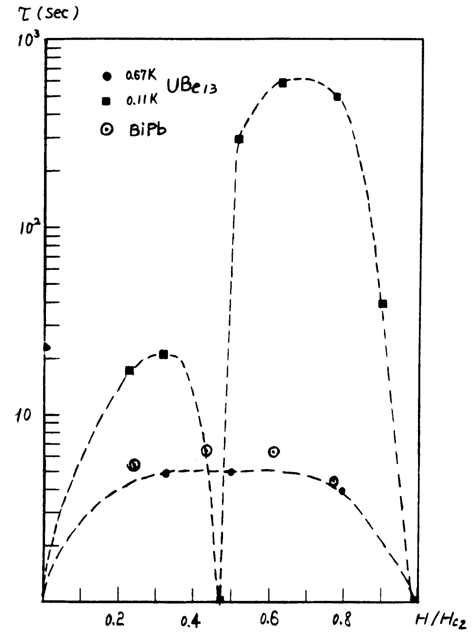

Fig. 3. Relaxation time vs reduced magnetic field H/H_{c2} for UBE_{13} and $Bi_{.5}Pb_{.5}$.

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