Physica C 185-189 (1991) 2633-2634
North-Holland

PHYSICA C

ANISOTROPY OF SUPERCONDUCTING PROPERTIES OF UPt_3 CLOSE TO T_c

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Experiments have been performed on the unconventional superconductor UPt_3 close to T_c. Topics that have been studied are: the double-step transition in the specific heat, the anisotropy in the enhanced conductivity above T_c and the low field ac susceptibility. A double-step structure has been observed in $\chi(T)$ as well for the ac field parallel to the c-axis. The low field penetration depth λ varies with temperature as $(T_c-T)^{-\beta}$ with β close to 1. These observations may be interpreted as a result of an interaction of the measuring current with vortices.

1. INTRODUCTION.

The anisotropic properties of the superconducting state in UPt_3 have been noticed in a number of experiments: ultrasound attenuation[1], thermal expansion[2], radio-frequency susceptibility. Significant anisotropies have been reported for the first[3] and second critical field[4]. However, some disagreement between the different results for the electrodynamic properties can be noticed. In order to further investigate these properties, measurements of the resistivity and ac susceptibility have been carried out on single-crystalline samples.

2. EXPERIMENTAL DETAILS.

Results are reported for two samples prepared by the Czochralski method[5], obtained from the same batch and labeled A and B. The largest dimension for sample A and sample B is along the c and b crystallografic directions, respectively. The current in the resistivity, and the field in the ac susceptibility measurements were applied along the longest edge of each sample. The specific heat has been measured by a relaxation technique. The results shown in Fig.1 are slightly different for the two samples.The onset temperature of the superconducting transition is the same and in both cases a trace of the two-step transition can be noticed.

3. RESULTS AND DISCUSSION.

The temperature dependence of the resistivity, $\rho=\rho_0+AT^2$, typical for heavy-fermion systems is observed above T_c, with ρ_0=1.35 and 0.70 $\mu\Omega$cm and A=1.65 and 0.69 $\mu\Omega cm/K^2$ for samples B and A, respectively. A feature not reported so far, is the pronounced difference in the superconducting transition width for both current directions. It is possible to use a

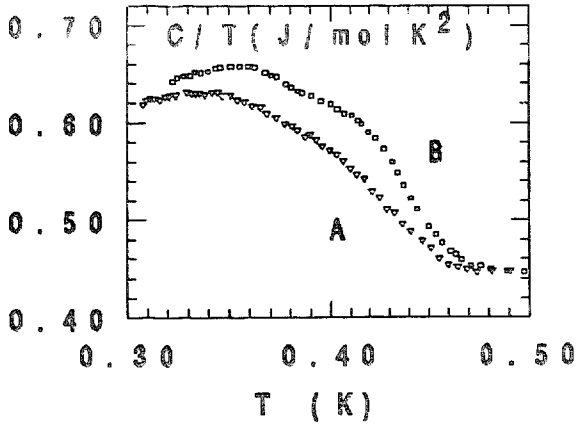

Fig.1: Specific heat for single crystalline UPt_3 in a plot of C/T vs. T.

simple power law to fit the temperature dependence of the enhanced conductivity:

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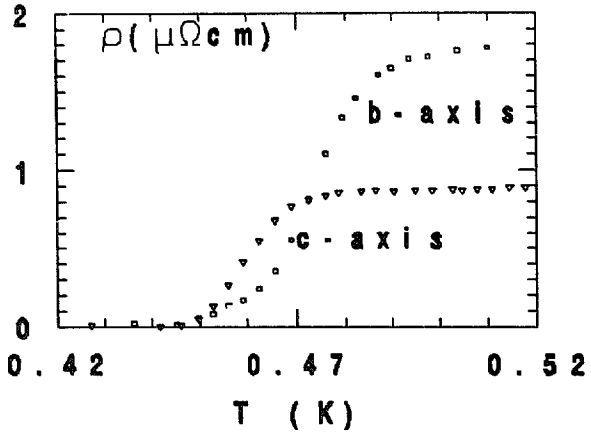

Fig.2: Resistivity for currents flowing along the b- and c-axis.

$\Delta\sigma=\sigma-\sigma_n \propto (T-T_c)^{-\gamma}$ For sample A the exponent γ is between 4 and 5. We can not exclude that the broadening is caused by inhomogeneities.

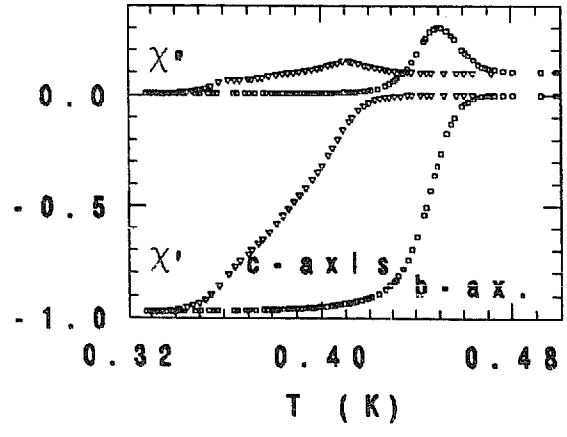

Fig.3: The complex ac susceptibility (in units of $1/4\pi$) for field direction parallel to the b- and c-axis.

The ac susceptibility has been measured with a frequency of 1000 Hz and a field amplitude of 0.35 Oe. Althogh we observe some frequency dependence of χ, essentially the same results are obtained at much smaller frequencies. A very huge anisotropy of the ac susceptibility is illustrated by the results displayed in Fig. 3. Additionally, for sample A a double-peak structure in $\chi''(T)$ is observed; the two maxima correspond well with the double-step transition in C(T). At lower temperatures the ac susceptibility is found to be independent of the ac field amplitude: this is manifested in independence of χ'' on temperature, below a certain temperature that depends on the ac field amplitude. The penetration depth deduced from $\chi'(T)$ under the assumption that the susceptibility can be approximated by that of a long cylinder, implies that the sample is not in the pure Meissner state: λ varies with temperature as $(T_c-T)^{-\beta}$ with β close to 1. The results suggests the presence of vortices interacting with the measuring current.

4. CONCLUSIONS.

Strong anisotropies are observed in the electrical resistivity and in the ac susceptibility of UPt_3 single crystals. The double-step SC transition in C(T) is also visible in $\chi(T)$ for fields parallel to the c-axis. The results are qualitatively consistent with the assumption of a spontanuous vortex states in the sample.

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