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ULTRASONIC ATTENUATION AND SOUND VELOCITY IN UPt_3

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We report measurements of the ultrasonic attenuation and sound velocity through the superconducting transition of UPt_3. The attenuation varies as T^2 at low temperatures and is inconsistent with the identification of UPt_3 as a singlet superconductor. Below T_c the sound velocity varies roughly as T^3 and above T_c as T^2. Our results indicate that UPt_3 is an anisotropic (triplet) superconductor in a polar-like state.

1. INTRODUCTION

There has been considerable recent interest in a group of superconductors which behave as Fermi liquids with large ($\sim 10^2 \rightarrow 10^3$) effective masses.[1] One of us has suggested that conventional s-wave paring is unlikely in these compounds and that a triplet mechanism must be involved.[2]

In this paper we report measurements of the ultrasonic attenuation and sound velocity in UPt_3 to temperatures well below T_c. The measurements were performed on a large crystal of UPt_3 synthesized in an arc furnace and then zone remelted. The sample was cut and polished to optical flatness. 50 MHz $LiNbO_3$ longitudinal transducers were fastened and the sample was mounted in an A.C. susceptibility coil so that the susceptibility and acoustical properties could be simultaneously measured.

In the figure we show the attenuation (measured at 507.9 MHz), the sound velocity and the ac susceptibility. Several points should be noted from the data: a) the attenuation near T_c approaches T_c with zero or a very small slope. For a singlet superconductor it should fall off very abruptly. b) At low temperatures the attenuation varies as T^2 and does not vary exponentially with temperature as is found for a singlet superconductor. c) The sound velocity varies as roughly T^3 below T_c and as T^2 above.

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The above observations are inconsistent with the identification of UPt_3 as a singlet superconductor. As will be shown below, the results however can be quite well explained by assuming that UPt_3 is a triplet superconductor in a polar-like state as suggested earlier,[3] based on the anisotropy of the critical fields[4].

For anisotropic (triplet) superconductors $\alpha s/\alpha n$ will depend on the type of state. These can be generally grouped into three classes:

i) states in which the gap exists over the entire Fermi surface (like the BW state in He^3). For these $\alpha s/\alpha n$ varies exponentially with temperature well below T_c.

ii) states (axial-like) which the gap vanishes at points on the Fermi surface (like the ABM state in He^3). For these $\alpha s/\alpha n$ goes as T^4 at low temperatures.

iii) states (polar-like) in which the gap vanishes at lines on the Fermi surface. For these $\alpha s/\alpha n$ goes as T^2 at low temperatures.

Our results for the attenuation therefore are strong evidence that UPt_3 is a triplet superconductor in a polar-like state.

The polar-like state would also give a sound velocity which should vary as T^3 (as opposed to T^5 for the axial-like state). This also agrees reasonably well with our results. Finally above T_c we find that the sound velocity varies as T^2. This is consistent thermodynamically with the large γ value of the specific heat seen for this compound.

In conclusion, we have measured the ultrasonic attenuation and sound velocity in UPt_3. The results are unambiguous that superconductivity in this compound is not due to singlet pairing. We obtain good agreement with a model assuming anisotropic (triplet) pairing in a polar-like state.

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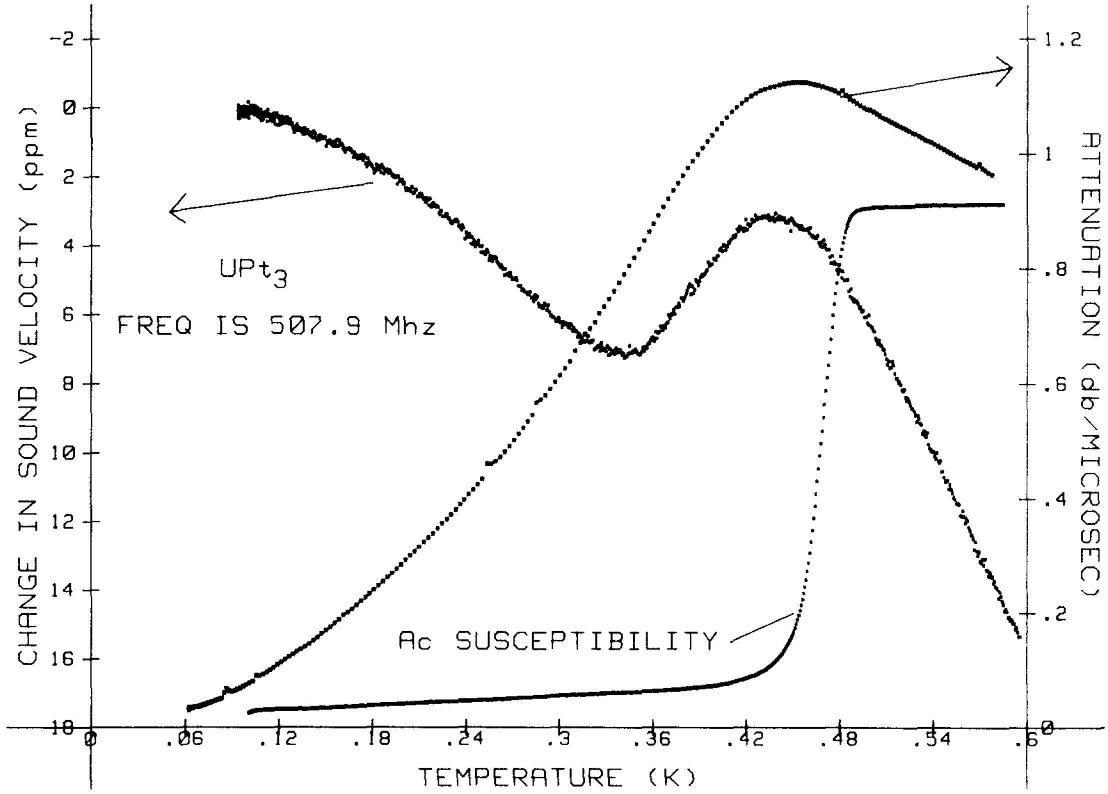

FIGURE 1
Shown are the attenuation, sound velocity and A_c susceptibility for UPt_3.