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YbB₁₂Pt (Ytterbium Bismuth Platinum): SDW? (Spin Density
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Fermi Surface Instability at 0.4K in a Heavy-Fermion YbBiPt: SDW?

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Abstract

We report results of resistivity measurements of heavy-fermion compound *YbBiPt* at ambient and hydrostatic pressures of up to $\approx 6\text{kbars}$ and in magnetic field up to 1Tesla . We interpret the rise of resistivity below 0.4K as partial gapping of the Fermi surface. From the temperature dependence of resistivity we obtain the value of the weak coupling energy gap of $\Delta_0/k_B T_c = 1.65 \pm 0.15$. Magnetic field - transition temperature phase diagram follows the weak coupling BCS expression remarkably well from T_c to $T_c/4$. These results support identification of 0.4K transition as a Spin Density Wave formation.

Interest in the compound YbBiPt has been sparked by the very large coefficient of the linear-in-temperature contribution to the heat capacity, $\gamma = 8\text{J/moleK}^2$, that develops at low temperatures [1]. Inelastic neutron scattering [2] suggests that some fraction of this large γ may arise from a Schottky contribution to the specific heat due to the existence of low-lying crystal-field excitations. However, separation of Schottky and intrinsic heavy-fermion contributions has not been possible. An intriguing aspect of this material is the existence of a magnetic phase transition at 0.4K that manifests itself as a small but rather sharp peak in specific heat. To address questions of the nature of the magnetic transition in *YbBiPt* and its groundstate, we have studied the electrical resistivity as a function of pressure and applied magnetic fields and we argue that these results, combined with specific

heat measurements, are consistent with the development of a spin density wave (SDW) below $0.4K$ in a heavy-mass band of conduction electrons.

Single-crystal samples of $YbBiPt$ were grown from an excess Bi flux [3]. X-ray diffraction confirms the samples to be face-centered cubic with the half-Heusler structure at room temperature.

Strong dependence of the SDW phase on pressure is seen as a consequence of the delicate Fermi-surface nesting that results in an SDW transition. Application of a rather small pressure, between 0.78 and $1.20kbar$ [4], suppresses any resistive signature for the low-temperature phase transition. Such high sensitivity to relatively small pressure again is consistent with the $0.4K$ transition in $YbBiPt$ being due to a Fermi-surface instability.

The relative rise of the resistivity below transition temperature in one of our samples is shown in Fig. 1. We have analyzed these data following McWhan and Rice's [5] approach to Cr which gives both the percentage of the Fermi surface that is gapped and the value of the SDW energy gap. Best fits to the data are obtained with $\Delta_0/k_B T_N = 1.65 \pm 0.15$, with $\approx 1/3$ of the Fermi surface gapped.

To further investigate this transition we performed a series of resistance measurements in a magnetic field. Figure 2 displays the resulting magnetic field-temperature phase diagram for the low temperature phase of $YbBiPt$. The solid curve is a BCS energy gap scaled to pass through the points $(T_c = .4K, H = 0)$ on the x-axis and $(T = 0, H = 3.1kG)$ on the y-axis. The curve fits the data very well, indicating the weak-coupling nature of the transition in the whole temperature range studied.

Within an SDW picture of the $0.4K$ phase transition in $YbBiPt$, it is now possible to estimate the heavy-fermion contribution to the low-temperature specific heat, which as mentioned in the introduction, is one of the central issues raised by $YbBiPt$. An equal-area construction [4] gives the ideal change in heat capacity at T_c of $\Delta C = 0.23 \pm 0.04 J/moleK$. Because the resistivity analyses indicate $YbBiPt$ follows weak-coupling BCS theory, we can use the value of $\Delta C/\gamma T_c = 1.43$. Taking into account that only about $1/3$ of the Fermi surface is gapped (Fig. 1), i.e., contributing to ΔC , this weak-coupling relation gives a Som-

Sommerfeld coefficient $\gamma = 1.2 \pm 0.2 J/moleK^2$ or about 15% of the total measured C_p/T near T_c and a value characteristic of very heavy fermion $Ce-$ and $U-$ based systems. We attribute non-heavy-fermion contribution principally to low-lying crystal-fields which produce substantial Schottky contributions to the specific heat at low temperatures [2].

In summary, below $T_c = 0.4K$ the resistivity of $YbBiPt$ becomes highly anisotropic with a gap over a part of the Fermi surface that can be described by weak-coupling energy gap $\Delta(T) = \Delta_0 f_{BCS}(T/T_c)$ with $\Delta_0/k_B T_c = 1.65 \pm 0.15$. The $H - T$ phase diagram is that of a classic weak-coupling transition, with the phase boundary closely following a BCS theory. We suggest that these observations are consistent with a spin-density wave transition in $YbBiPt$ at $0.4K$ that gaps $\approx 1/3$ of the Fermi surface. This identification is supported further by the extreme pressure dependence of the transition temperature. Analysis of the specific heat near T_c in view of this interpretation indicates that the SDW occurs within a strongly renormalized band of heavy fermions with Sommerfeld coefficient $\gamma = 1.2 J/moleK^2$.

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FIGURES

FIG. 1. Scaled resistivity increase for the sample of Fig. 1(b), for the direction of the larger increase. The solid line is result of analysis similar to McWhan *et al.*, with $\Delta_0/k_B T_c = 1.6$.

FIG. 2. Magnetic field - Temperature phase diagram for low temperature phase of *YbBiPt*. The solid and open symbols are results of the temperature and magnetic field sweeps, respectively. The solid line is a BCS curve fixed by the points $(H, T = 0)$ and $(H = 0, T_c)$.

— fig. 1, Mozhovich et al., ... yB Bi Pt...

— fig 2, Monstreich et al., ... 1983, Pt...

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