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Journal
Physica B Condensed Matter, 199(C)

ISSN
0921-4526

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Publication Date
1994-04-01

DOI
10.1016/0921-4526(94)91752-3

ELSEVIER

Physica B 199&200 (1994) 113–115

PHYSICA B

Magnetic ordering in YbBiPt

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Abstract

The field dependence of the μSR relaxation function in YbBiPt, together with an anisotropic resistive anomaly recently discovered by Movshovich et al., indicate that both the Yb ions and the conduction electrons undergo magnetic ordering. New evidence is also presented for a change in Yb spin-ordering or spin-dynamics below about 0.1 K.

The properties of YbBiPt [1, 2] have attracted attention primarily because of the very large linear coefficient of specific heat γ (8 J/mol Yb K^2) at low temperatures and a partially characterized phase transition at $T_C = 0.4$ K, which has been shown to be magnetic by zero-field μSR experiments [3, 4]. Recent resistivity measurements [5] show an anisotropic resistance anomaly at 0.4 K suggesting a Fermi surface which is gapped in one or more directions. This behavior disappears near 0.3 T applied field, where the resistive transition is apparently destroyed.

Previously reported zero-field μSR measurements [3, 4] on crystalline and crushed-powder samples of (Yb$_x$Y$_{1-x}$) BiPt can be parameterized by a relaxation function displaying both fast and slowly relaxing components. In zero applied field the fast component is Gaussian below T_C and exponential above, whereas the slow component remains exponential at all temperatures. The Gaussian relaxation rate (about 8 μs^{-1}) is consistent with an ordered Yb moment $\approx 0.1\ \mu_B$, in accordance with the lack of a nuclear Schottky anomaly in the low-temperature specific heat [2]. One interpretation [3, 4] of these results is in terms of different magnetic regions with different characteristic relaxation rates. Below we present new data on the field dependence of the relaxation function above and below T_C in crystalline YbBiPt and discuss a related physical model which is consistent with several aspects of the resistivity, specific heat and μSR data. We also present evidence for a change in spin structure below about 0.1 K.

The experiments were carried out at the Low Temperature Facility of the Paul Scherrer Institute in Villigen, Switzerland. The samples were prepared at Los Alamos by the flux-growth technique and several pieces of crystalline material were glued to the cryostat cold finger.

Fig. 1 shows the longitudinal-field relaxation functions at $T = 0.08$ K taken in applied field of 0.01, 0.03 and 0.5 T. The fast component has a reduced amplitude at higher fields, characteristic of a quasi-static field distribution [6]. The observed early-time Gaussian character may be due to fields random in direction and magnitude as mentioned previously [3, 4] or, alternatively, to an

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SSDI 921-4526(93)E0412-A

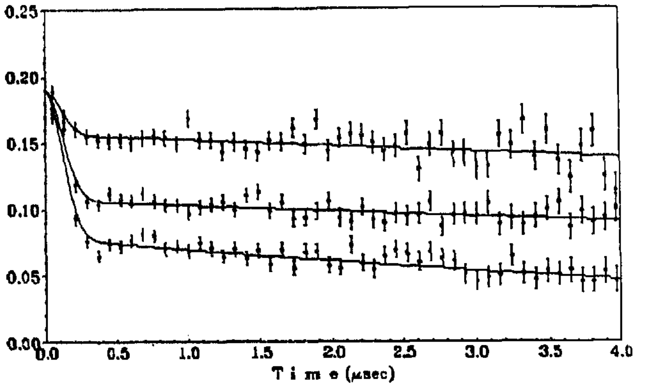

Fig. 1. Decay of the muon polarization versus time in YbBiPt at $T = 0.08$ K for applied fields of 0.01 T (bottom), 0.03 T (middle) and 0.5 T (top). The vertical scale is in arbitrary units.

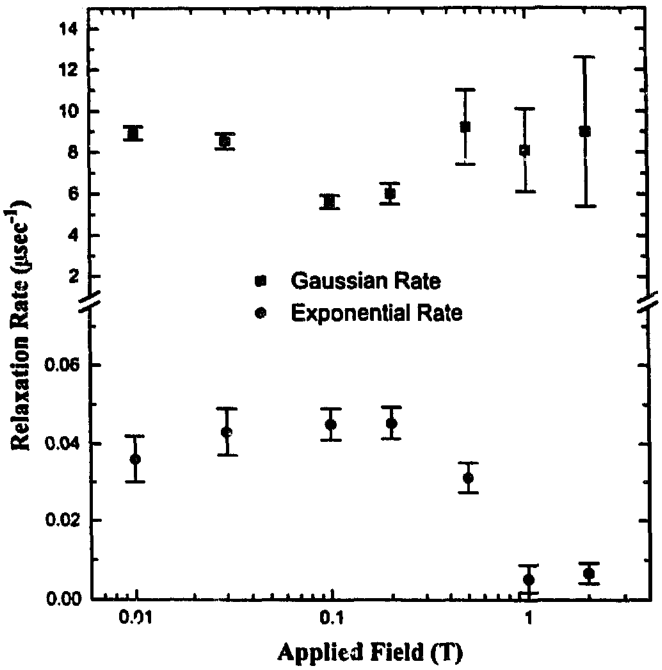

Fig. 2. Field dependence of the quasi-static (top) and dynamical (bottom) μSR relaxation rates in YbBiPt at $T = 0.1$ K.

ordered magnetic state if the damping is sufficiently rapid. We will show elsewhere that an incommensurate modulation of the antiferromagnetic (AFM) spin density can produce such behavior. For this case one can model a single-component relaxation function with a two component fit, where the fast and slow components are produced by quasi-static fields below T_C and a broad distribution of fluctuation rates above T_C. Alternatively, the muon may sense regions of high and low spin density, each giving rise to different magnetic behavior. A two-component relaxation function has been observed in $Cr_{85}Mo_{15}$, which possesses an incommensurate spin density wave (SDW) [7].

Fig. 2 shows a plot of the field dependence of the rates of the fast Gaussian and slow exponential relaxation components as a function of applied field for $T = 0.1$ K. The fast quasi-static rate is independent of field up to 2 T, whereas the Fermi surface instability responsible for the anisotropic resistivity anomaly disappears above 0.3 T applied field. This can be understood by assuming that the muons primarily sense the Yb quasi-static field distribution, whereas the resistive transport is affected by the conduction electron density of states which is gapped by a SDW. The μSR and resistivity data taken together therefore imply that both the Yb local moments and the conduction electrons undergo ordering near the characteristic temperature 0.4 K. The applied field of 0.3 T is sufficient to destroy the SDW ordering, but not the Yb ordering, assuming the ordered Yb moment is quite small ($\approx 0.1\ \mu_B$). Note that the Zeeman splitting produced by 0.3 T is about equal to the characteristic temperature of 0.4 K for 1 μ_B but not for 0.1 μ_B. The reduction in the exponential relaxation rate at low field reflects the local field dynamics and may be associated with the destruction of the SDW.

Rare earth metals are known to exhibit super-zone gaps in which a magnetic periodicity of finite Q in the rare earth ions modifies the conduction band structure to produce a spin density wave which gaps the Fermi surface [8]. An applied magnetic field can destroy this AFM by direct coupling to the SDW, or by inducing a ferromagnetic structure in the rare earth ordering. If the latter occurred in YbBiPt, one would expect that the fast μSR linewidth would change both shape and magnitude as the Yb ions reorient in the field. Fig. 2 shows, however, that the magnitude of the linewidth remains unchanged up to 2 T. The shape of the line at high fields is difficult to determine because of the reduced amplitude. One should also consider possible effects of the muon's electric field gradient on the local spin system at these low temperatures.

We have also measured the spin-lattice relaxation rate above T_C in applied fields of 0.6 T. The data are well described by a stretched exponential $\exp(-Dt)^k$, where both D and k are functions of temperature. At 60 K, k is near 1, whereas near 1 K, k approaches 1/2. This stretched-exponential behavior indicates a broad distribution of local-field correlation times as the material cools to low temperatures. Also, the field dependence of the

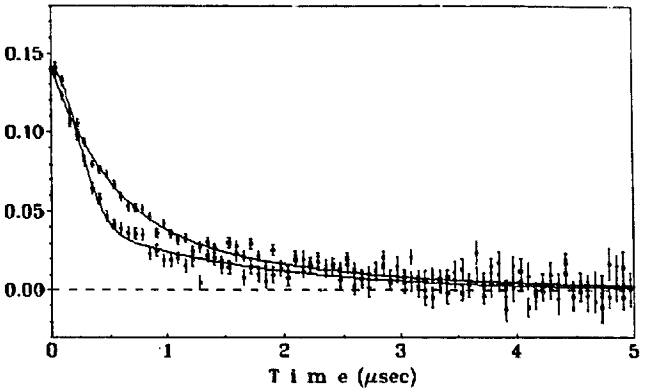

Fig. 3. Decay of the zero-field muon polarization versus time in YbBiPt at $T = 0.125$ K (lower curve) and $T = 0.06$ K (upper curve). The best fit for the fast component changes from Gaussian to exponential as the temperature is lowered. The vertical scale is in arbitrary units.

spin-lattice relaxation rate is relatively weak; a power-law behavior close to $1/\sqrt{H}$ is seen above T_C, as found in systems possessing a high degree of frustration [9].

Fig. 3 shows two high-statistics spectra in zero field taken at $T = 0.125$ K and $T = 0.06$ K. Another high statistics spectrum taken at $T = 0.25$ K is almost identical to the spectrum at $T = 0.125$ K. Two points are important. First, the Gaussian linewidths from these samples are about one-half those reported above in different crystalline samples, indicating sample-dependent differences in magnetic structure or muon position, possibly strain induced. Second, the lowest temperature data give evidence for a change in either the spin dynamics or spin structure as the temperature is lowered somewhere below 0.125 K. Evidence for a possible phase transition below 0.1 K has also been seen in susceptibility and specific heat data [2]. Additional μSR experiments are planned to investigate this phenomenon.

This work was supported in part by the US Department of Energy, Office of Basic Energy Sciences and by the National Science Foundation, Grant No. DMR-9114911.

References

[1] Z. Fisk et al., Phys. Rev. Lett. 67 (1991) 3310.
[2] J.D. Thompson et al., Physica B 186–188 (1993) 355.
[3] A. Amato et al., Phys. Rev. B 46 (1992) 3151
[4] A. Amato et al., Physica B 186–188 (1993) 615.
[5] R. Movshovich et al., Physica B 199&200 (1994) 67.
[6] R. Kubo and T. Toyabe in: Magnetic Resonance and Relaxation (North-Holland, Amsterdam, 1967) p. 810
[7] M.T.F. Telling et al., in: Sixth International Conference on Muon Spin Rotation (Hawaii, 1993).
[8] A.J. Freeman, in: Magnetic Properties of Rare Earth Metals (Plenum, London, 1972), p. 245.
[9] D.E. MacLaughlin et al., Phys. Rev. Lett. 51 (1983) 927.