Effect of sample "quality" on the galvanomagnetic properties of UBe_{13}

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The magnetoresistance of many UBe_{13} samples with various values of $\rho_{300\,K}$ ($10^{-6} - 5\times 10^{-6}\ \Omega\cdot m$) has been studied over the temperature interval from 0.6 to 4.2 K. Measurements were taken in static magnetic fields (up to 22 T) and pulsed magnetic fields (up to 43 T). Some possible causes of a pronounced decrease in the resistance of the samples in a magnetic field are suggested.

The heavy-fermion compound UBe_{13} has several interesting features in both its normal and superconducting states, as has been pointed out elsewhere.[1,2] As the temperature is lowered from 300 K, for example, the resistance of UBe_{13} samples usually increases by a factor of about two, goes through a maximum at $T\approx 2.5$ K, and then decreases, vanishing at $T<0.95$ K. In addition to the fairly sharp maximum at $T\approx 2.5$ K, curves of $\rho(T)$ for UBe_{13} samples have a smooth inflection point at $T\approx 30$ K. For lower-quality UBe_{13} samples, e.g., samples which have been bombarded with neutrons or doped with a small amount of an impurity, the resistivity at room temperature, $\rho_{300\,K}$, is larger, and the $\rho(T)$ curve has a broad maximum, instead of an inflection point; the sharp maximum at 2.5 K disappears. As was pointed out in Ref. 3, the dependence $\rho(T)$ for neutron-bombarded UBe_{13} samples becomes similar to that of the nonsuperconducting heavy-fermion compound $CeAl_3$.

The effect of an external magnetic field of the $\rho(T)$ curve of UBe_{13} samples is particularly strong at low temperatures. In particular, at $T = 1.9$ K an increase in the field from 0 to 20 T reduces $\rho(T)$ by 70% (Ref. 4).

In this letter we are reporting measurements of the magnetoresistance of samples varying in "quality" in fields up to 45 T.

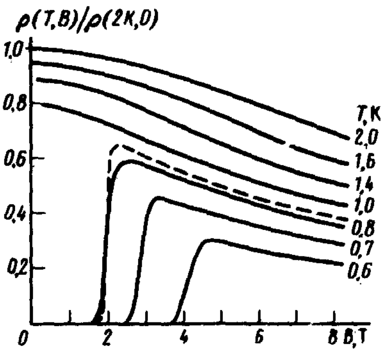

FIG. 1. Isotherms of the dependence of the resistance on the magnetic field for one of the UBe_{13} samples, with $\rho_{300\ K} \sim 10^{-6}\ \Omega\cdot m$, found in fields up to 9 T at several temperatures, ranging from 0.6 to 2 K. The dashed line is one of the $\rho(B)$ curves at $T = 0.8$ K from Ref. 6.

We believe that one of the basic "quality" criteria of UBe_{13} samples is the value of $\rho_{300\ K}$. Samples differing in "quality" were prepared by heat treatment of UBe_{13} in a "toroid" pressure chamber. We also used UBe_{13} samples synthesized under various conditions and doped with small amounts of Zr or Fe.

Figure 1 shows isotherms of the dependence of the resistance on the magnetic field, $\rho(B)|_{T=\text{const}}$, measured in fields up to 9 T at several temperatures from 0.6 to 2 K, for one of the samples, with $\rho_{300\ K} \sim 10^{-6}\ \Omega\cdot m$.

The samples are cooled below 1.2 K by means of adiabatic demagnetization of erbium-doped yttrium aluminum garnet in an apparatus similar to that described in Ref. 5.

It can be seen from Fig. 1 that, for example, at $T = 0.6$ K in a field $B > 3$ T, the suppression of the superconductivity of the sample results in a resistance, which reaches a maximum at $B \approx 4.7$ T and then falls off gradually with increasing field. These results agree well with the corresponding curves of $\rho(B)|_{T=\text{const}}$ for a UBe_{13} samples with approximately the same value of $\rho_{300\ K}$ from Ref. 6.

Figure 2a shows values of $\rho(B)$ measured at $T = 1.8$ and 4.2 K in static magnetic fields up to 22 T and in pulsed fields up to 42 T for two single crystals with $\rho_{300\ K} = 1.4\times10^{-6}\ \Omega\cdot m$ and $1.2\times10^{-6}\ \Omega\cdot m$, cut along the C_2 and C_4 axes, respectively. The results found in the static and pulsed fields[1)] with a pulse length $\sim 10^{-2}$ s agree well. It can be seen from Fig. 2a that for two samples in different orientations the resistance decreases in an essentially identical way, by a factor of about 10 in a 42-T field. Figure 2b shows values of $\rho(B)$ versus $\log B$ for a sample with the orientation $J \| C_2$. If we extrapolate this behavior to stronger fields, we find that $\rho(B)$ can vanish[2)] at $B = 50$–60 T. Preliminary measurements at a lower temperature ($T = 1.27$ K) lead to the conclusion that the value of $\rho(B)/\rho(0)$ drops below 3% in a 42-T field.

Comparison of the data found for the various samples (Fig. 3) shows that the samples with the minimum values of $\rho_{300\ K}$ exhibit the most pronounced decrease in resistance in a magnetic field.[3)] If we assume that the nature of the change in $\rho(14T)/\rho(0)$ as a function of $\log \rho_{300\ K}$ at $T = 1.8$ K can be described approximately by a straight line even at lower values of $\rho_{300\ K}$, we would expect that for a hypothetical

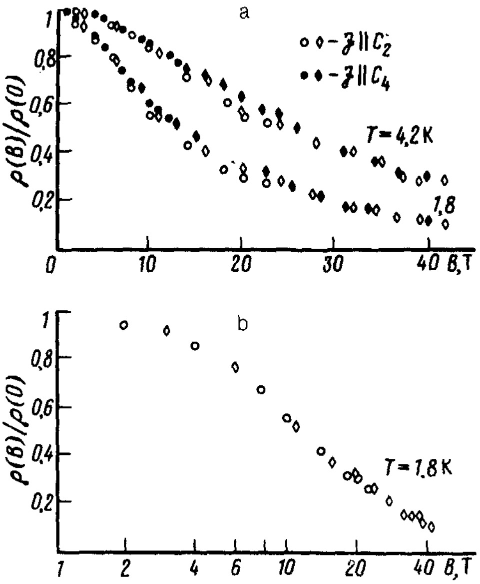

FIG. 2. a: Results of measurements of the magnetoresistance of UBe_{13} single crystals at $T = 1.8$ K and 4.2 K. ○, ◇— The crystals are cut along the C_2 axis; ●, ◆—along the C_4 axis; ○, ●—in a static magnetic field; ◇, ◆—in a pulsed magnetic field. b: Magnetoresistance of a UBe_{13} sample cut along the C_2 axis versus $\log B$ ($T = 1.8$ K).

sample with $\rho_{300\,\mathrm{K}} \leqslant 7 \times 10^{-8}\ \Omega \cdot \mathrm{m}$ the resistance at 1.8 K would be close to zero in a 14-T field.

There are several possibilities for explaining the pronounced decreases in the resistivity in a magnetic field. One possibility in the case of UBe_{13}, as has been pointed out previously,[4] might be that this is a case of a magnetic-field-induced superconductivity, which has been discovered in $Eu_{1-x}Sn_xMo_6S_{7.2}Se_{0.8}$, for example.[7] Other possible explanations for the pronounced decrease in $\rho(B)$ with the field might be particular features of the magnetic properties of UBe_{13} and an unusual nature of the interaction of the current carriers from different bands, which lead to, for example, an s-f hybridization.[8]

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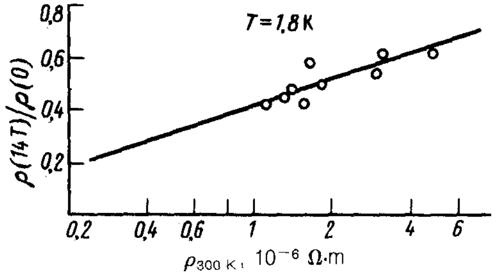

FIG. 3. Magnetoresistance of UBe_{13} samples with various values of $\rho_{300\,\mathrm{K}}$ in a 14-T field at $T = 1.8$ K.

[1] In all cases, the measurement current in the sample was perpendicular to the direction of the magnetic field.

[2] Remenyi *et al.*[6] believe that the $\rho(B)$ dependence which they found at $T = 0.48$ K in fields up to 23 T does not tend toward zero. However, there is still the possibility that for samples of higher quality the $\rho(B)$ dependence might be even steeper at these values of T and B.

[3] Attempts to anneal the samples in an inert atmosphere in order to achieve lower values of $\rho_{300\,\mathrm{K}}$ resulted in a disintegration to the samples.

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