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DOI

[10.1016/0921-4534\(94\)92104-0](https://doi.org/10.1016/0921-4534(94)92104-0)

Publication date

1994

Published in

Physica C

[Link to publication](#)

Citation for published version (APA):

Kierspel, H., Kopanakis, E., Buchner, B., Freimuth, A., Schlabit, W., Duijn, V. H. M., Hien, N. T., Menovsky, A. A., & Franse, J. J. M. (1994). Bi₂Sr₂CaCu₂O₈+delta in magnetic fields up to 16 Tesla. *Physica C*, 235-240, 1765-1766. [https://doi.org/10.1016/0921-4534\(94\)92104-0](https://doi.org/10.1016/0921-4534(94)92104-0)

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Specific Heat of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+x}$ in Magnetic Fields up to 16 Tesla

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High resolution specific heat measurements of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+x}$ superconductors in magnetic fields up to 16 Tesla are presented. In a polycrystalline sample the magnetic field leads to a drastic suppression and a pronounced broadening of the anomaly at T_c . In contrast, our measurements on a high quality single crystal for fields parallel to the CuO_2 -layers do not show any significant suppression of the specific heat at T_c . Moreover, the specific heat above T_c , which is attributed to superconducting fluctuations, decreases. As a consequence the anomaly at T_c appears to become sharper with increasing magnetic field.

Due to the unusual superconducting properties of the high T_c superconductors (HTSC), pronounced fluctuations of the order parameter are observed in a rather wide temperature range around T_c in these materials [1]. The analysis of the specific heat anomaly at T_c is well suited to investigate these fluctuations in zero magnetic field. In a magnetic field the superconducting fluctuations are proposed to be enhanced, due to a reduction of their dimensionality [2]. This is confirmed experimentally e.g. from specific heat measurements in high magnetic fields on Y123 [3].

In the present study we have investigated the specific heat of a polycrystalline and a single crystalline sample of the strongly anisotropic Bi2212.

The specific heat between 40K and 300K in magnetic fields up to 16T was measured in a high resolution calorimeter using the adiabatic, continuous heating technique. The large ($20 \times 5 \times 0.5 \text{ mm}^3$, 173mg) high quality Bi2212 single crystal was grown in air using the travelling solvent floating zone technique [4]. This method yields slightly overdoped samples with $T_c \simeq 85\text{K}$. The polycrystal with $T_c = 92\text{K}$ has been prepared by standard solid state reaction.

In Fig. 1 we plot the specific heat of the polycrystalline sample close to T_c in magnetic fields between 0 and 16T. The anomaly for $H = 0\text{T}$ shows strong fluctuations and a rather small mean field step, which is typical for the Bi2212

compounds [1,5]. The very strong influence of magnetic fields is apparent: We find both, a strong suppression as well as a pronounced broadening of the anomaly with increasing magnetic field. On the other hand, due to the large H_{c2} the decrease of the critical temperature is only small, our measurements yield $dT_c/dH < 0.15\text{K/T}$. The data obtained for the polycrystalline sample are similar to those found in other studies [6].

The specific heat of the Bi2212 single crystal is shown in Fig. 2. The upper curve was measured in zero magnetic field. To our knowledge this is

Figure 1 Specific heat C/T vs. temperature of polycrystalline Bi2212 for $H = 0\text{T}$, 7T , 16T .

Figure 2. Specific heat C/T vs. temperature of single crystalline Bi2212 for $H = 0\text{ T}$ and 14 T .

the first observation of a specific heat anomaly at T_c in a Bi2212 single crystal, which confirms that our sample is of high quality. The difference of the anomalies in zero magnetic field in Fig. 1 and 2 as well as that of T_c is due to the higher oxygen content of the single crystal, i.e. the shape and the size of the anomaly found in the single crystal compares well to that of polycrystalline samples with the same T_c , i.e. the same oxygen content [5,6].

To study the influence of the magnetic field on this anomaly we have measured the specific heat in six magnetic fields between 0 and 14 T parallel to the CuO_2 -planes. The data for $H = 14\text{ T}$ plotted in Fig. 2 are representative for all other measurements, i.e. the specific heat for smaller fields interpolates smoothly between the two curves shown.

It is apparent that the magnetic field parallel to the CuO_2 -planes does not suppress the specific heat jump. Moreover there is no evidence for any broadening of the anomaly. Instead the anomaly appears to become sharper in high magnetic fields. Obviously the behavior found for $H||a, b$ is *qualitatively* different from that of our polycrystalline sample (Fig. 1)

Inspecting the data of Fig. 2 more closely we find that the main influence of the magnetic field occurs above T_c : The superconducting fluctuations in this temperature range or more precisely

their contribution to the specific heat appear to be reduced. This is not due to a decrease of T_c , which is nearly independent of field in agreement with the very high H_{c2} . From our data we have to conclude that in highly anisotropic Bi2212 a magnetic field $H||a, b$ does *not* lead to an enhancement of the superconducting fluctuations. Moreover, the behavior for $H||a, b$ is qualitatively different from that found in the polycrystal, where the latter probably reflects the behavior for $H||c$. Direct measurements for $H||c$ are in progress to check this presumption.

Our findings are in striking contrast to the results obtained on a Y123 single crystal, where a broadening of the specific heat anomaly is observed for both field directions [3]. Moreover, the anomaly of the specific heat measured for $H||a, b \simeq 10\text{ T}$ – 15 T compares well to that found for a smaller field $H||c = 2.5\text{ T}$, i.e. the specific heat anomaly in Y123 is simply anisotropic with respect to the direction between the magnetic field and the crystal axes and thus yields a bulk measurement of this anisotropy. From our data such a simple anisotropic behavior is very unlikely to occur in Bi2212.

In conclusion we have presented the first measurements of the specific heat anomaly of a Bi2212 single crystal in magnetic fields. For magnetic fields parallel to the CuO_2 -planes we find a decrease of the fluctuation specific heat above T_c with increasing magnetic field, which leads to a sharpening of the anomaly at T_c .

This work was supported by the DFG through SFB 341.

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