Superconductivity in sintered-polycrystalline PrBa$_2$Cu$_3$O$_{7-\delta}$

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Abstract

Superconductivity in thin films and powders, and in single crystals of PrBa$_2$Cu$_3$O$_{7-\delta}$ has been found by Blackstead et al. and Zou et al., respectively. Nevertheless, up to now it has never been reported in sintered-polycrystalline samples. We have prepared high-quality samples of this material by following a sol–gel method. We characterized the structure of all samples by using XRD and SEM-EDS techniques. Magnetic characterization was performed by measuring the magnetization as a function of temperature $T$, and the applied magnetic field $H$. Measurements were taken in the ranges $2 \text{ K} < T < 400 \text{ K}$ and $0 < H < 5 \text{ T}$. In this work we report for the first time superconductivity in PrBa$_2$Cu$_3$O$_{7-\delta}$ sintered-polycrystalline samples, with $T_c$ around 90 K, and $H_c1$ around 870 Oe.

Keywords: Magnetization; PrBaCuO

Since the early years of high-temperature superconductivity, all rare earths (RE) participating in the structure REBa$_2$Cu$_3$O$_{7-\delta}$ were found to be superconductors, with one exception: RE = Pr, forming PrBa$_2$Cu$_3$O$_{7-\delta}$, also called PBCO. However, in 1995, Blackstead et al. [1] verified superconductivity in PBCO powders and in thin films grown by pulsed laser deposition (PLD). They pointed out that perfect PBCO should be the superconductor in the vicinity of the Cu–O chains, so that cuprate-plane models of superconductivity should be invalid. On the other hand, in 1997 Zou et al., detected superconductivity in PBCO single crystals [2], grown by both slow-cooling and the travelling-solvent floating-zone methods. Nevertheless, superconductivity in sintered-polycrystalline PBCO samples has never been reported. This has been considered consistent with previous works pointing out the high sensitivity of the properties of PBCO to the synthesis conditions. This lack of superconducting polycrystalline PBCO samples has been one of the main points supporting the theory that considers the supression of $T_c$ as a consequence of the presence of Ba-site Pr.

We report in this work, for the first time, superconductivity in high-quality sintered-polycrystalline PBCO samples, obtained by a sol–gel technique.

Magnetic characterization was performed by using a Quantum Design-MPMS-5 SQUID magnetometer through $M(T)$ and $M(H)$ experiments, for different values of the applied magnetic field and temperature. $M(T)$ were performed in zero-field cooling (ZFC) conditions. These results were obtained (Fig. 1) by substracting the paramagnetic background. To do that, we have considered that, for temperatures high enough ($T > 200 \text{ K}$), superconductivity has been suppressed, remaining the Curie–Weiss paramagnetic background. For the $M(H)$ experiments (Fig. 2) we have also substracted a paramagnetic background consisting of a straight line. The line coefficients were calculated from a pure paramagnetic behavior present in high fields ($H > 4 \text{ T}$), and at temperatures higher than $T_c$ ($T > 200 \text{ K}$). The results obtained through this procedure are in perfect agreement with
those expected for a superconductor. Curves of $M(T)$ show broad superconducting transitions, with $T_c$ around 90 K for all measured samples (Fig. 1). Curves of $M(H)$ show a linear diamagnetic behavior up to around 870 Oe for $T = 30$ K, which should correspond to the lower critical magnetic field, $H_{c1}$ (Fig. 2). Contributions from sample holder has already been subtracted. From these experiments we have estimated in about 5% the superconducting fraction.

In summary, in this work we report for the first time superconductivity in polycrystalline PBCO samples, obtained by a sol–gel route. The quality of the samples has been verified through X-ray diffraction and scanning electron microscopy with local chemical analysis. All magnetic experiments performed, magnetization as a function of temperature for different values of the applied magnetic field, and magnetization as a function of the applied magnetic field, for different values of the temperature, have revealed the typical behavior of a superconductor. The obtained results for the critical temperature and lower critical magnetic field are in perfect agreement with those reported for single crystals and thin films of PBCO.

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References