

Field-induced phase transition, weak ferromagnetism, and metamagnetic transition in the underdoped PrBCO cuprate

Thursday 25 July 2024 14:00 (2 hours)

We report anomalous magnetic properties in high DC magnetic fields H up to 16 T on an underdoped $\text{PrBa}_2\text{Cu}_3\text{O}_{6.44}$ insulating ceramic sample of cuprate family. Significant magnetic-field effects are revealed in the derivative $dM(T)/dT$ of the magnetization $M(T)$ versus T using two sets of values of H selected in the range of 2.5-9.5 T. Anomalies are observed in the region of $T_{\text{cr}} \sim 4.5$ K, $T_2 \sim 6.5$ K and $T_N = 9$ K, which are respectively the well-known low-critical point, the spin reorientation phase transition temperature, and the Néel temperature of the antiferromagnetic (AFM) ordering of the Pr^{3+} sublattice [1]. Using Arrott plot analysis, we identified at 1.35 K weak field-induced phase transitions at two critical fields, $H_{\text{cr}1} \sim 3.3$ T and $H_{\text{cr}2} \sim 7.5$ T, whose associated transition lines appear temperature-independent as T increases up to T_2 , and seem to vanish in the vicinity of T_N . Between T_N and 20 K, the curves of the derivative $dM(H)/dH$ of the magnetization $M(H)$ versus H show a slight increase when H is taken in the low-field range of $0.7 \text{ T} < H_S < 1.2 \text{ T}$. The field H_S being the specific field above which the weak ferromagnetic (WFM) part settles in the Pr AFM regime as well as in the AFM state of the $\text{Cu}(2)$ spins which takes place in the region of room temperature. As T decreases, H_S increases monotonically, while $dM(H)/dH$ exhibits a high-speed increase below T_{cr} . The $M(H)$ curves obtained with a high accuracy, show obviously a linear field dependence in the range of H_S - $H_{\text{cr}1}$, so, they may be represented by the equation $MS(T) + \chi_d(T)H$. The spontaneous magnetization $MS(T)$ and the differential magnetic susceptibility $\chi_d(T)$ are obtained by extrapolation to zero-field from the linear part of the $M(H)$ curves in the low-field range ($H_S < H < 2 \text{ T}$). $MS(T)$ decreases as the inverse of T , like for paramagnetic systems with a shape change when crossing T_N and survives above T_N . Whereas $\chi_d(T)$ has a behavior practically analogous to that of AFM materials and shows a shape change when crossing T_{cr} , T_2 , and T_N . The $M(H) - \chi_d(T)H$ versus H curves present a metamagnetic-like field-induced transition at a threshold field H_t for H lower than 0.15 T. These anomalous features observed at low temperatures and surviving above T_N , are taken as evidence for an additional weak ferromagnetic-like component. The results are compared with previous neutron-scattering study [2] and discussed in terms of the significant role of the Pr-Cu(2) coupling which appear to continue well above T_N .

[1] M. Lahoubi, Physica B 536 (2018) 12.

[2] A. T. Boothroyd et al., phys. Rev. Lett., 78 (1997) 130.

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Session Classification: Thu-Po-3.6

Track Classification: Tracks ICMC Geneva 2024: ICMC 03: Bulk material processing, properties and applications