High-Field Exploration of Charge Order in Underdoped $YBa_2Cu_3O_{6.77}$

M. Hirata, H. Mayaffre, S. Kraemer, M. Horvatic, C. Berthier, M-H. Julien (LNCMI Grenoble, France); P.L. Kuhns, A.P. Reyes (NHMFL); R. Liang, W. N. Hardy, D.A. Bonn (University of British Columbia, Canadian Institute for Advanced Research)

Introduction

The recent discovery of long-range charge-density-wave (CDW) order competing with superconductivity in underdoped $YBa_2Cu_3O_y$ (YBCO) [1] constitutes a significant step in the research on high-T_C superconductivity because it supports the idea that charge order is a generic instability in underdoped cuprates. In order to further clarify the possible relationship of the CDW with superconductivity, an important question is how the CDW evolves as a function of doping across the phase diagram. Here we expand our previous works on YBCO [1] and report high-field (H) ^{17}O-NMR evidence of charge order in YBCO with a doping level of p = 0.136 (ortho-III).

Experimental

^{17}O-NMR measurements were performed on an underdoped $YBa_2Cu_3O_{6.77}$ single crystal in fields from H = 30 up to 45 T in the hybrid magnet at the NHMFL. The splitting of the ^{17}O-NMR 2nd-high-frequency satellite $\Delta\nu_{tot}$, which is known to be linked to the long-range CDW order [1], is measured at T = 2.5 K.

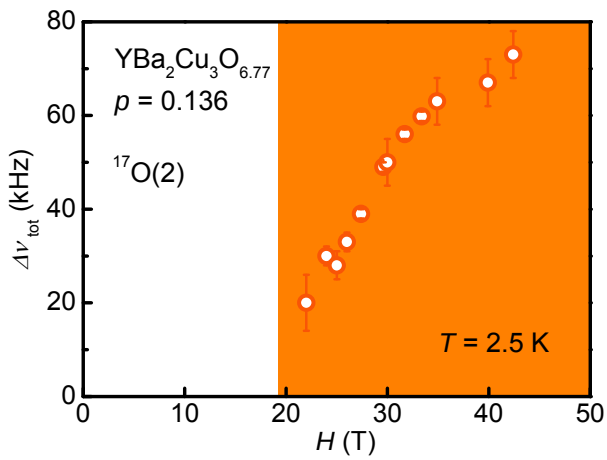

Figure 1. The ^{17}O-NMR total line splitting at the highest-frequency quadrupole satellite of planar O(2) sites (close to $H||c$). The data points below 30 T were measured in Grenoble. Total values, instead of the c-axis component, of the field are used here.

Results and Discussion

The experiment at the NHMFL has allowed us to reach the regime in which the total line splitting $\Delta\nu_{tot}$ is linear as a function of field (Fig. 1). This indicates that the quadrupole splitting $\Delta\nu_{quad}$ (related to the amplitude of the charge modulation) becomes independent of the field above $H \approx$ 35-40 T. This field scale is remarkably similar to the upper critical field H_{c2} for this doping level [2, 3]. This result appears to be in agreement with our earlier work where we proposed that the amplitude of the charge modulation, that is, the CDW order parameter, no longer depends on field once superconductivity has been entirely quenched [1]. In the same sample, we observed a square-root-like increase of $\Delta\nu_{quad}$ above a threshold field of $H_{charge} \approx$ 20-23 T, that is significantly higher than $H_{charge} \approx$ 10 T at doping levels around $p \approx$ 0.11-0.12 [1].

Conclusions

The results confirm the previously established picture that the field scales associated with the onset and with the saturation of the long-range CDW order in YBCO have the same doping dependence as the superconducting upper critical field H_{c2}, with a minimum at doping levels near $p \approx$ 0.11-0.12. These results establish a connection between CDW and superconducting orders, which is yet to be understood. Further analyses of the data, currently in progress, should allow addressing the doping dependence of the amplitude of the charge modulation.

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References

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