Angular-dependent Upper Critical Field of Overdoped $Ba(Fe_{1-x}Ni_x)_2As_2$

J. Murphy, M. A. Tanatar, S. L. Bud'ko, P. C. Canfield, R. Prozorov (Iowa State Univ./Ames Laboratory), D. Graf, J. S. Brooks (FSU/NHMFL)

Introduction

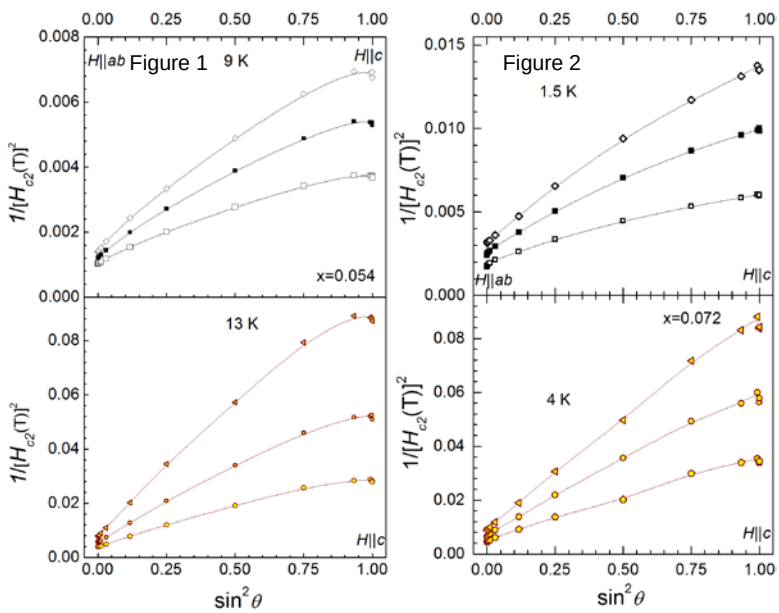
The temperature and angular dependencies of the upper critical field, H_{c2}, contain information about the superconducting gap structure. Strong doping dependence of the superconducting gap anisotropy was reported in electron – doped iron – based superconductors. Here we study Hc2 in overdoped $Ba(Fe_{1-x}Ni_x)_2As_2$ in which nodes along the c-axis were suggested [1].

Experimental

In-plane resistivity measurements as a function of temperature, magnetic field and its orientation with respect to the crystal were used to study the Hc2 in two overdoped compositions of $Ba(Fe_{1-x}Ni_x)_2As_2$ (x=0.054 and x=0.072). Measurements were performed using precise alignment (with accuracy less than 0.1^o) of a magnetic field direction with respect to the conducting Fe-As-planes. The Hc2 vs the angle θ between the field direction and the ab-plane was measured in isothermal conditions in a temperature range close to zero-field transition, $T_c(H=0)$, and at low temperatures $T << T_c(0)$.

Results and Discussion

We found that the shape of $H_{c2}(T)$ clearly differs for the two principal directions of the magnetic field, along and perpendicular to the tetragonal c-axis. Importantly, at both temperatures we found that the shape of $H_{c2}(\theta)$, clearly deviates from the Ginzburg-Landau functional form, expected for orbital limiting. To illustrate this, we plot in **Figure 1** and **Figure 2** the $1/H^2_{c2}$ vs. $\sin^2\theta$ showing clear deviation from the expected linear dependence.



Figures 1,2: Angular dependence $H_{c2}(\theta)$, determined from fixed temperature ρ(H) using 20%, 50% and 80% criteria (top to bottom), (Fig.1, left) for slightly overdoped $Ba(Fe_{1-x}Ni_x)_2As_2$, x=0.054 at 9~K (top panel) and 13~K (bottom panel) and (Fig.2, right) x=0.072 at 1.5~K (top panel) and 4~K (bottom panel). The data are plotted as $H_{c2}^{-2}(\sin^2(\theta))$, which should be a straight line for Ginzburg-Landau functional form.

Conclusions

By performing high angular resolution studies of H_{c2} in two overdoped compositions of $Ba(Fe_{1-x}Ni_x)_2As_2$, we find clear deviations from the anisotropic Ginzburg-Landau functional dependence. We suggest that this may reflect c-axis modulation of the superconducting gap, as suggested by anisotropic penetration depth and thermal conductivity measurements [1,2].

Acknowledgements

Work at the Ames Laboratory was supported by the Department of Energy-Basic Energy Sciences under Contract No. DE-AC02-07CH11358.

References

[1] C. Martin, H. Kim, R. T. Gordon, N. Ni, V. G. Kogan, S. L. Bud'ko, P. C. Canfield, M. A. Tanatar, and R. Prozorov, Phys. Rev. B **81**, 060505 (2010).
[2] J.-Ph. Reid, M. A. Tanatar, H. Shakeripour, X. G. Luo, N. Doiron-Leyraud, N. Ni, S. L. Bud'ko, P. C. Canfield, R. Prozorov, and L. Taillefer, Phys. Rev. B **82,** 064501 (2010).