The effect of low Ni-for-Fe ($x \leq 0.07$) doping on the magnetically ordered superconductor $RbEu(Fe_{1-x}Ni_x)_4As_4$ in fields up to 65 T

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Introduction

In the magnetically ordered superconductor $RbEuFe_4As_4$ (T_c ~ 36.5 K, T_m ~ 15 K) [1,2], it is possible to dope Ni on the Fe site, which suppresses T_c but not the temperature at which the Eu spin lattice magnetically orders [3]. Above a critical doping level, the spin-density wave observed in many FeAs-derived superconductors reappears. We have measured the magnetic phase diagram of $RbEu(Fe_{1-x}Ni_x)_4As_4$ single crystals in pulsed magnetic fields up to 65 T for several doping levels below this critical value. Up to x=0.05, the anisotropy is suppressed with increased doping; above this level, the anisotropy grows again. $H_{c2}(T=0)$ is weakly suppressed for low doping levels.

Experimental

The proximity detector oscillator (PDO) technique was used to measure superconducting transitions on single crystals of $RbEu(Fe_{1-x}Ni_x)_4As_4$ with H // (110) and H // (001) at various temperatures in pulsed magnetic fields up to 65 T using the NHFML 65 T Pulse Field Facility at Los Alamos National Laboratory.

Results and Discussion

In **Fig. 1** we show zero field-cooled magnetic susceptibility vs temperature of $RbEu(Fe_{1-x}Ni_x)_4As_4$ with H // (110) in 100 G. As doping increases, T_c is suppressed, but T_m does not change; the diamagnetic screening becomes less effective. No evidence of spin-density-wave formation is seen at any doping level. In **Fig. 2**, we show the pulse field measurement-derived magnetic phase diagram, with each curve normalized to its zero-field transition temperature. The pronounced curvature of the x=0 curve for H // (110) is suppressed by Ni doping; the data approach a universal isotropic curve. Additional doping breaks this trend; this may be due to a change in the Fermi surface. There is surprisingly little variation in the extrapolated $H_{c2}(T=0)$; the origin of this is unclear. Increased electron scattering should destabilize a possible FFLO state at low temperature / high field, but this is not consistent with the increased anisotropy found in the x=0.07 material.

Conclusions

Instead of suppressing $H_{c2}(T=0)$ to a value accessible in the 65 T instrumental limit, enabling measurement of the full magnetic phase boundary, Ni-doping suppresses the importance of Pauli paramagnetic pairbreaking, removing the strong curvature. At higher doping, this trend is broken, and the anisotropy and strong curvature reappear. The origin of this behavior is not clear, and may be due to a change in the Fermi surface. This should be investigated further as soon as higher doped single crystals become available.

Acknowledgements

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References

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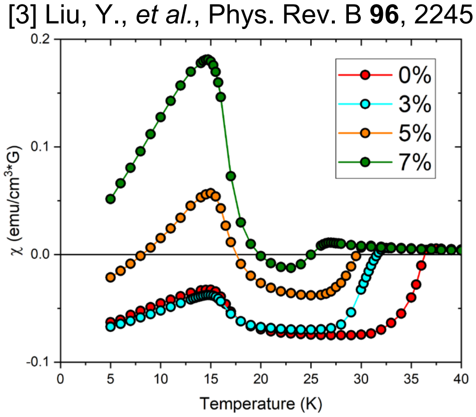

Fig.1 Magnetic susceptibility vs T of $RbEu(Fe_{1-x}Ni_x)_4As_4$ with H // (110) in 100 G. As doping increases, T_c is suppressed but T_m is not; diamagnetic screening decreases.

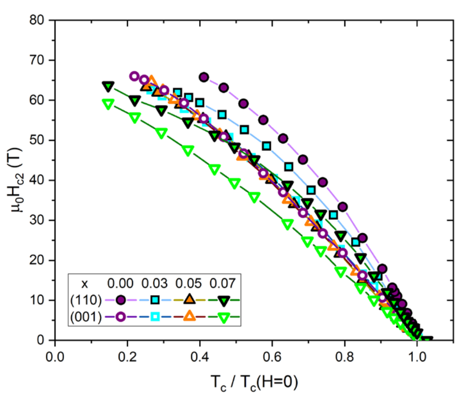

Fig.2 Magnetic phase diagram of $RbEu(Fe_{1-x}Ni_x)_4As_4$, normalized to T_c/T_{c0}. As doping increases, a universal isotropic curve is approached until x=0.07, when the anisotropy reappears.