Magneto-transport properties and thermally activated flux flow
Ba(Fe$_{0.95}$Ni$_{0.05}$)$_2$As$_2$ and Ba(Fe$_{0.94}$Ni$_{0.06}$)$_2$As$_2$ superconductors

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Measurement

Resistivity vs. temperature in fields 0-18 T

Analysis

The Anderson-Kim Arrhenius TAFF model

$$\rho = \rho_0 \exp(-U(T,H)/k_BT)$$

$$d\ln \rho / d(1/T) = -U/k_B$$

Modified Anderson model

$$d\ln \rho / d(1/T) = \frac{U_0^2}{k_B T} \left(\frac{1}{T}\right)$$

$$\rho = \rho_0 \exp(-\frac{U_0^2}{2k_BT})$$

Slope of $d\ln \rho / d(1/T)$ gives $U_0^2/k_B$

Results

Pinning potential energy and resistivity vs. temperature for 0, 1, and 2 T

The TAFF boundary forms a narrow deep valley of decreasing depth across the $T$-$H$ plane as $H$ is increasing. It is about 0.4 to 1.7 K wide.

Conclusion

The onset of fluctuations is seen as the resistivity shows the first signs of an increase but this initial rise does not fit the Arrhenius TAFF model for we do not get a clearly defined slope that defines the activation energy $U$.

There is an onset of weak pinning at $T_c$ (TAFF off) in low fields. As we move vertically across the $T$-$H$ phase curve, staying above $T_c$, the weak pinning strength decreases to zero as the field increases from 0 T to 18 T and we get an unpinned vortex fluid.

Just below $T_c$, we see the onset of weak pinning that turns to no pinning as we approach $H_T$. This is not an abrupt first-order transition, but a continuous one where weak pinning and no pinning regimes coexist. In other words, the vortex fluid phase is a fully disordered phase, which is not separated from the normal phase by a true phase transition—they really are the same phase and are connected by a smooth crossover.

We determine the flux flow activation energies of Ba(Fe$_{0.95}$Ni$_{0.05}$)$_2$As$_2$ and Ba(Fe$_{0.94}$Ni$_{0.06}$)$_2$As$_2$ bulk superconductors as a function of magnetic field and temperature.

We determine the upper critical field and the $H$-$T$ phase diagram with particular emphasis on the limitations of the Anderson-Kim TAFF regime.