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Reversal of the Upper Critical Field Anisotropy and Spin-Locked Superconductivity in $K_2Cr_3As_3$

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Introduction

Recently, superconductivity in $K_2Cr_3As_3$ ($T_c = 6.1$ K) [1] was discovered. The crystalline lattice contains an array of weakly coupled, double well $[(Cr_3As_3)^{2-}]_\infty$ linkages stretched along the c axis, suggesting the possibility of quasi-one-dimensional superconductivity. Moderately anisotropic upper critical field was revealed in single crystals [2], with very large initial slopes, $dH_{c2}^{\parallel}/dT = 12$ T/K along the Cr chains and $dH_{c2}^{\perp}/dT = 7$ T/K perpendicular to the chains. Given the ambiguity of conclusions based on the extrapolations of $H_{c2}(T)$ measured near T_c to low temperatures, we performed high-field measurements of $H_{c2}(T)$ on $K_2Cr_3As_3$ single crystals in pulsed magnetic fields which enabled us to reveal the full anisotropic $H_{c2}(T)$ curves from T_c down to 600 mK.

Experimental

The H_{c2} below 4 K was measured in a 65 T pulsed magnet at the National High Magnetic Field Laboratory (NHMFL), Los Alamos, using a contactless technique based on a proximity detector oscillator (PDO). A $K_2Cr_3As_3$ crystal was separated into several pieces and placed, one parallel to field and the other perpendicular to field, on two separate spiral copper coils (Fig.1). The lithographically defined resonating RF coils were designed at NHMFL. The coils are connected to a PDO resonating in the 30-35 MHz range. The oscillatory signal waveforms were recorded directly using a fast 200 million samples per second digitizer during 120 ms magnet pulse.

Results and Discussion

We find that the $H_{c2}^{\parallel}(T)$ exhibits a paramagnetically-limited behavior, whereas no evidence of paramagnetic pair breaking was observed for $H_{c2}^{\perp}(T)$ (Fig.2). As a result, the curves $H_{c2}^{\parallel}(T)$ and $H_{c2}^{\perp}(T)$ cross at $T \sim 4$ K, so that the anisotropy parameter $\gamma(T) = H_{c2}^{\perp} / H_{c2}^{\parallel}$ increases from $\gamma \sim 0.35$ near T_c to $\gamma \sim 1.7$ at 0.6 K. This behavior of $H_{c2}(T)$ is inconsistent with triplet superconductivity but suggests a form of singlet superconductivity with the electron spins locked onto the direction of Cr chains [3].

Acknowledgements

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References

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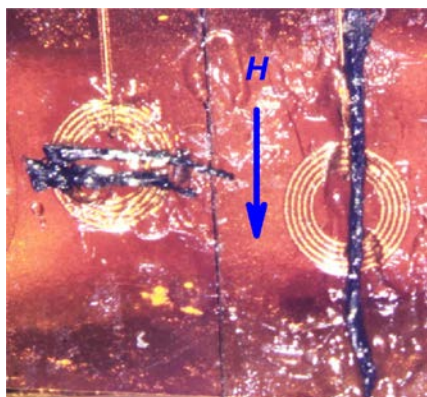


Fig.1 Parts of a single crystal sample mounted on PDO coils. The coils are planar spiral coils, coil geometry preferable for coupling to rod-like samples. Magnetic field direction is shown by the blue arrow.

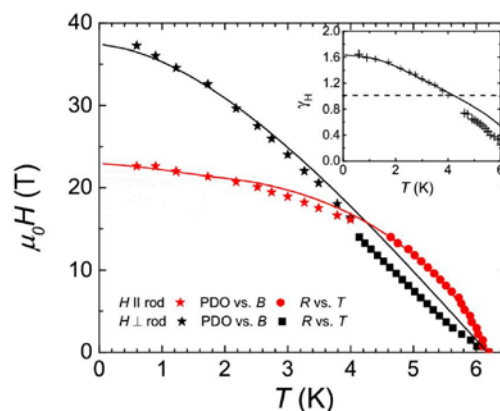


Fig.2 Upper critical fields H_{c2} along c -axis (red) and perpendicular to c -axis (black), symbols. Solid lines are fits to Werthamer-Helfand-Hohenberg theory for a uniaxial superconductor. Inset shows $\gamma(T) = H_{c2}^{\perp} / H_{c2}^{\parallel}$.