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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 $d\,H_{c2}^{\perp}/dT$ =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~4 K, so that the anisotropy parameter $\gamma(T)= H_{c2}^{\perp} / H_{c2}^{\parallel}$.increases from γ~0.35 near T_c to γ~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].

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References

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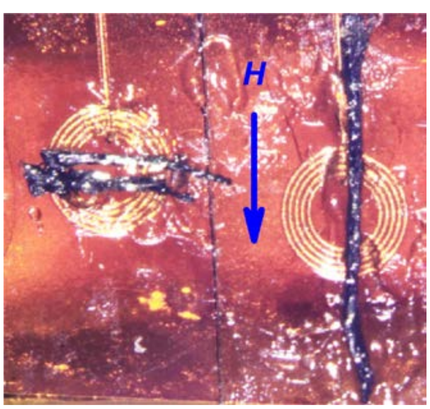

Fig.1 Parts of a single crystal sample mounted on PDO coils. The coils are planar spiral coils, coil geometry preferable for coupling to rod-like samples. Magnetic field direction is shown by the blue arrow.

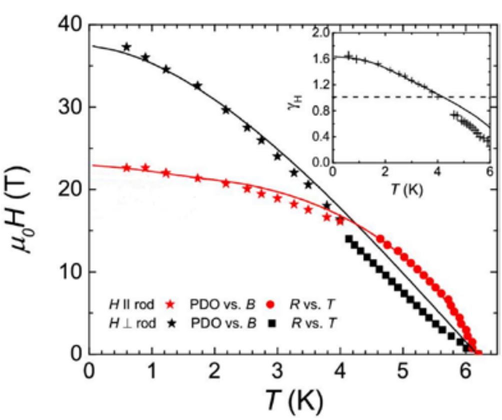

Fig.2 Upper critical fields H_{c2} along c-axis (red) and perpendicular to c-axis (black), symbols. Solid lines are fits to Werthamer-Helfand-Hohenberg theory for a uniaxial superconductor. Inset shows $\gamma(T)= H_{c2}^{\perp} / H_{c2}^{\parallel}$.