Nodeless Superconducting State in the Presence of Zero-Field Staggered Magnetization in $CeRh_2As_2$

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The tetragonal heavy-fermion superconductor $CeRh_2As_2$ with a critical temperature $T_c \approx 0.35\,\mathrm{K}$ exhibits an intriguing magnetic field-induced transition between likely distinct superconducting states. In zero field, an even-parity state emerges within another ordered phase of unknown origin with $T_0 \approx 0.54\,\mathrm{K}$. Here, we study local magnetization using micro-Hall probe magnetometry to test the order-parameter symmetry of the spin-singlet state in $CeRh_2As_2$ and to reveal the nature of the T_0 phase.

The temperature dependence of the lower critical field $H_{c1}(T)$ down to $\approx 0.02T_c$ was investigated for several samples prepared from single crystals grown by different methods. For both in-plane and out-of-plane field directions, the $H_{c1}(T)$ can be well described by the conventional relation derived from the Bardeen-Cooper-Schrieffer theory with $\Delta(0) = 1.764\,k_BT_c$, indicating consistency with fully gapped superconductivity. Furthermore, we observed that $H_{c1}(T)$ shows the same T^2 behavior for both high-quality and lower-quality samples ($T_c \approx 0.21\,\mathrm{K}$, $T_0 \approx 0.32\,\mathrm{K}$) in nearly the same temperature range up to $0.6T_c$, thereby disfavoring a dirty d-wave scenario.

In the normal state below T_0, we found a clear increase in the in-plane magnetization, while no similar feature was observed along the c axis. Its magnitude is sensitively dependent on the sample quality, but it was also detected in a lower-quality single crystal. One can relate the local magnetization in the order of 10^{-1}–10^{-3} μB/Ce atom to the presence of antiferromagnetic domains and domain walls in $CeRh_2As_2$. This observation is in line with recent proposal for the behavior of the T_0 phase under magnetic fields applied for in-plane direction [1].

Our results place important constraints on the spin-singlet order parameter in $CeRh_2As_2$ and highlight an important role of static magnetic moments in the nature of T_0 phase, within which a Cooper pairing occurs [2].

References:

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[2] J. Juraszek, G. Chajewski, D. Kaczorowski, M. Konczykowski, D.F. Agterberg, and T. Cichorek, arXiv:2502.14423 (2025).

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