Two-band superconductivity in the prototypical heavy-fermion compound $CeCu_2Si_2$ studied by local magnetization measurements

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The discovery of the first heavy-fermion superconductor $CeCu_2Si_2$ was a turning point in the history of superconductivity because it led to the birth of research on unconventional pairing [1]. While the superconductivity of $CeCu_2Si_2$ is closely linked to an antiferromagnetic quantum critical point, the unexpected observations of the multiband superconductivity with absence of nodal quasiparticles have challenged the long-held dichotomy between simple *s*- and *d*-wave spin-singlet pairing states [2,3].

We present in- and out-of-plane temperature dependencies of the lower critical field $H_{c1}(T)$ of $CeCu_2Si_2$ (a critical temperature $T_c \simeq 0.58\,\mathrm{K}$, *S*-type sample) probed by local magnetization measurements performed down to 7 mK using a newly-developed Hall-probe magnetometry [4]. For both the [100] and [001] directions, we found sharp anomalies (at $\simeq 0.34T_c$ and $\simeq 0.41T_c$, respectively) followed by moderate enhancements, indicative of two nearly decoupled bands. Moreover, the $H_{c1}(T)$ curves saturate in the limit $T = 0$, providing a further support for the absence of nodal quasiparticles. A result of our fitting of the $H_{c1}(T)$ curves with a self-consistent γ-model turns out to be more consistent with an $s_{\pm}$-wave scenario with weak interband coupling than a $d_{xy} + d_{x^2-y^2}$ model. In addition to this, we studied the effect of electron irradiation on $H_{c1}(T)$. We observe irradiation to strongly suppress the enhancement of H_{c1} connected with the small gap and this enhancement for $H \parallel [001]$ is hardly visible for a dose as small as $0.8\,\mathrm{C/cm^2}$. However, the $H_{c1}(T)$ dependence above $\simeq 0.4T_c$, which is well described by a single-band BCS-like relation, is robust against disorder for both the crystallographic directions. In addition, the el-irradiation effect on T_c is small and nearly isotropic with a rate of $0.027(2)\,\mathrm{Kcm^2/C}$. Summing up, the saturation of $H_{c1}(T)$ at the lowest temperatures and the strong effect of nonmagnetic disorder on the H_{c1} enhancement at $T \ll T_c$ seem to favor an $s_{\pm}$-wave scenario.

References:

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