The potential impact of Andreev bound states on the Bean-Livingston barrier in chiral superconductor 4Hb-TaS_2

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The interplay of a quantum spin liquid with itinerant conduction electrons is a likely source of unconventional superconductivity in the van der Waals heterostructure 4Hb-TaS_2 [1]. Below the critical temperature $T_c \simeq 2.7$ K, this polymorph of tantalum disulfide, consisting of alternating layers of 1T-TaS_2 (quantum spin liquid) and 1H-TaS_2, (half of 2H-TaS_2, a BCS superconductor), exhibits a sign of spontaneous time-reversal symmetry breaking, as seen in the μSR signal [1]. Furthermore, several peculiar properties of the vortex state, including topological edge modes [2] and the magnetic memory effect [3] studied by scanning tunneling microscopy, point to chiral superconductivity in this highly interesting superconductor. However, the symmetry of the superconducting order parameter of 4Hb-TaS_2 is poorly understood from bulk measurements.

Here, we investigate vortex penetration into 4Hb-TaS_2 for a magnetic field parallel to the layers stacking direction. Using micro-Hall-probe magnetometry [4], we focus on the field of first flux penetration and the resultant temperature dependence of the lower critical field $H_{c1}(T)$ in the entire superconducting state down to $0.002T_c$. For platelet-shaped samples with the thickness $d < 10$ μm, we found that the out-of-plane $H_{c1}(T)$ dependence can be well described by the conventional relation derived from the BCS theory, pointing to marginal multiband effects and suggesting a nodeless superconducting order parameter of 4Hb-TaS_2. However, with increasing thickness we observed an anomalous enhancement of the penetration field deep in the superconducting state. Specifically, samples with $d \simeq 200$ μm show the pronounced enhancement of H_{c1} at $0.5T_c$, which consists of a non-saturating T-dependence down to 0.007 K (the lowest temperature in the experiment). Our results appear to be consistent with the theoretically predicted effect of Andreev bound states on the Bean-Livingston barrier, and thus provide macroscopic evidence for a sign-changing gap function in the candidate chiral superconductor 4Hb-TaS_2.

References:

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