Low-Temperature Surface Conduction in the Topological Kondo Insulator SmB_6: A Two-Fluid Perspective

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Samarium hexaboride (SmB_6), a well-known Kondo insulator, remains a long-standing mystery due to its unusual low-temperature (T) behavior arising from the interplay of strong electron correlations and nontrivial band topology [1]. While $d-f$ hybridization of Sm electrons opens up a uniform Kondo gap of $\sim$ 10–20 meV, the odd-parity band inversion gives rise to a Z_2 topological insulating character, establishing SmB_6 as the first prospective topological Kondo insulator candidate [1]. At $T \sim$ 30–50 K, the resistivity ρ increases sharply due to bulk gap opening and subsequently saturates into a puzzling low-T ($\leqslant$ 5 K) resistivity plateau. This feature is widely interpreted as evidence for low-temperature surface-dominated conduction, further supported by quantum oscillation and spectroscopic studies, although the precise topological nature of the surface states remains debated [1].

In this work [2], using a novel non-contact two-coil mutual inductance (TCMI) technique, complemented by DC resistivity (ρ) and magnetic susceptibility (χ) measurements, we identify three distinct temperature regimes in SmB_6: (i) $T > T^*(\sim 62$ K), (ii) (23 K$\sim$)$T_g < T < T^*$, (iii) $T < T_g$ [2,3]. Our TCMI results, supported by specific heat and I–V measurements, reveal a clear split between bulk ($T_k \sim 116$ K) and surface ($T_k^s \approx 7$ K) Kondo temperatures, attributed to surface-disorder-induced Kondo breakdown (KB) [4], which releases magnetic fluctuations below T^*. At $T < T_g$, these magnetic fluctuations subside, leading to the revival of surface Kondo screening. Concomitantly, an in-gap state ($\sim$ 2.2 meV) emerges within the Kondo gap, hosting light, Dirac-like charge carriers. Nyquist impedance analysis of the TCMI response reveals a crossover from purely capacitive behavior at high T to a non-ideal capacitive–inductive response at low T. This behavior is consistent with an inhomogeneous low-temperature admixture of heavy quasiparticles released by surface KB and light, high-mobility Dirac-like carriers. Furthermore, we identify a novel characteristic length scale $L_{\nu_0}(T)$ quantifying the phase volume of the light, highly conducting, low-scattering (topological) component of the fluid present on the SmB_6 surface, which diverges below T_k^s. Our study establishes a non-ideal two-fluid description of the long-debated low-T surface conduction in SmB_6.

References:

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