Possible Field-Induced Superconductivity in Quasi-One-Dimensional Li$_{0.9}$Mo$_6$O$_{17}$

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Introduction

Li$_{0.9}$Mo$_6$O$_{17}$ (LMO) is one of a class of low dimensional conductors known as molybdenum oxide bronzes, though in contrast to its quasi-2D Na and K analogs, LMO has a highly anisotropic quasi-1D electronic structure. LMO is metallic at room temperature, semiconducting below a temperature $T_{\text{min}} \sim 25$ K and in clean crystals, it becomes superconducting below $T_c \sim 1.8$ K [1]. The origin of the resistive upturn below $T_{\text{min}}$ has not yet been resolved, with charge density wave (CDW) formation, spin density wave (SDW) formation and strong localization all put forward as possible origins. In order to study the origin of this metal-insulator crossover, we have carried out the first detailed magneto resistance (MR) study of LMO single crystals in the non-metallic regime below $T_{\text{min}}$ at fields up to 45 Tesla.

Results and Discussion

With the field applied parallel to the most conducting direction, a large negative MR is observed. With increasing field strength, a metallic state is recovered. Analysis suggests that this insulator/metal crossover is driven by the field suppression of an energy gap associated with an ordered state, such as a CDW or SDW or Mott gap, which is responsible for the activated behaviour in the resistivity. This suppression is found to be highly dependent on the orientation of the magnetic field.

At the highest fields studied, beyond the field range where the metallic state is restored, we uncover a striking new feature in the physics of LMO. Figure 1 shows the in-chain resistivity of one LMO sample measured in an applied field of 45 Tesla. A sharp downturn in the high-field resistivity is observed at low temperatures, heralding the transition to a superconducting state with an onset $T_c >10$ K. Significantly, the onset temperature is almost one order of magnitude larger than that seen in zero field (note however that this particular sample was non-superconducting in zero-field). Moreover, the field at which superconductivity survives is well above the Pauli paramagnetic limit expected for a 10 K BCS superconductor and, in contrast to what is observed in conventional superconductors, $T_c(H)$ continues to increase with increasing field. These features are consistent with theoretical predictions for the high-field behavior of re-entrant quasi-1D superconductors [2] (including those with triplet pairing), though such a strong enhancement of $T_c$ is anomalous and demands further study.

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References