In recent years, the search for non-trivial topological materials has become a hot topic in condensed matter physics. Since Hor et al, first reported the discovery of superconductivity in Cu doped topological material Bi$_2$Se$_3$ in 2010, the Cu$_x$Bi$_2$Se$_3$ has become one of the most promising materials as topological superconductor due to its unique physical properties and crystal structure. However, the superconducting transition temperature Tc up to 3.8 K in Cu$_x$Bi$_2$Se$_3$ is unexpectedly “high” for a low carrier density semiconductor. So far, the mechanism of such anomalous enhanced Tc phenomenon remains unclear despite nearly a decade of extensive research.

In a recent work conducted by Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, high quality single crystal of Cu$_x$Bi$_2$Se$_3$ was grown by modified Bridgman method. The Tc of the as-grown crystals with x=0.09 could reach 4.18 K, which was the highest one among reports on Cu$_x$Bi$_2$Se$_3$ so far.

A systematic study of the magnetic susceptibility, critical fields, and electrical transport on the Cu$_{0.09}$Bi$_2$Se$_3$ single crystals were conducted to explore the unusually enhanced Tc and its superconducting properties.

Interestingly, a novel kink in the magnetic susceptibility versus temperature was observed at 96 K, which indicated a charge density anomaly, probably charge density wave (CDW) transition. The analysis of the magnetoelectrical transport at low temperature yielded a high Kadowaki-Woods ratio, which might be enhanced by the charge density instability and/or strong electronic anisotropy.

Based on the lower critical field measurement, the energy gap ratio $\Delta_0/k_BT_c$ was found obviously larger than the standard BCS value 1.764, suggesting the Cu$_{0.09}$Bi$_2$Se$_3$ a strong-coupling superconductor. Ratios of both Tc/TF2D and Tc/$\Delta_0/2(0)$ fell into the region of unconventional superconductors according to Uemura's regime, supporting the unconventional superconducting mechanism in Cu$_x$Bi$_2$Se$_3$.

Their research proposed that the high Tc in Cu$_x$Bi$_2$Se$_3$ arises from the increased density of states at Fermi energy and strong electron-phonon interaction induced by the charge density instability.

The results suggest the higher Tc in Cu$_{0.09}$Bi$_2$Se$_3$ could be further achieved by gating-technique or high pressure technique, as realized in iron-selenides superconductors.

Provided by Chinese Academy of Sciences