Abstract

Recently, BiS_2-based layered superconductors have emerged as new members of the family of layered superconductors. Their phase diagram is extremely rich which exhibits coexistence of apparently antagonistic phenomena like, ferromagnetism and superconductivity. These systems show striking structural similarities with the high temperature superconductors like the cuprates and the ferropnictides. Consequently, it is believed that understanding of the mechanism through which superconductivity emerges in BiS_2-based superconductors will provide useful information for developing a concrete theory for describing high temperature superconductors in general.

In this thesis, I present transport spectroscopic studies on certain BiS_2-based superconductors. To perform such experiments, I first built a new point contact spectroscopy probe working down to a temperature of 300 mK and up to a magnetic field of 7 Tesla. I used this probe to study two important candidates of the BiS_2 family (i) $Sr_{0.5}Ce_{0.5}FBiS_2$ and (ii) La(O,F)BiSeS. From direct measurement of the superconducting energy gap, I have shown that the superconducting order parameter in these systems shows two-fold anisotropy in the momentum space indicating the presence of a non-trivial symmetry of the order parameter. In addition, I have also observed the emergence of a pseudo-gap like feature that competes with superconductivity. I have shown that the pseudo-gap feature can be attributed to nesting of a multi-band Fermi surface and a significant electron-phonon coupling that could result in charge density wave-like instabilities.

I will also present about some of my sub-kelvin and high-field experiments for probing the mechanism through which superconductivity gets enhanced in certain mesoscopic superconductors. I have shown that under mesoscopic point contacts, the superconducting properties of elemental zirconium (Zr) exhibit a giant 5-fold enhancement. I found that such enhancement is due to the appearance of a new electron-band in the Fermi level of such point contacts.

In the end of this thesis I will be discussing on one of the important works carried on Weyl semimetal NbP. As this work does not have direct correlation with rest of my thesis work, so it is presented in the appendix.