Title:	Probing Conventional and Unconventional Superconductivity by Ultra-Low-Temperature Scanning Tunneling Spectroscopy
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Abstract:	Primarily, in this thesis, the focus has been to study superconductivity in certain topologically non-trivial materials using scanning tunneling microscopy and spectroscopy (STM/STS). Scanning Tunneling Spectroscopy (STS) is a powerful tool to probe the quasi-particle density of states in a conducting solid. A spectral gap, if any, can thus be directly probed by this technique. We have used an ultra-low temperature (down to 300 mK) and ultra-high vacuum (10-11 mbar) STM to study the nature of pairing in some of the candidate exotic superconductors. The major results, procured in this work are highlighted below. Multiband superconductor Mo8Ga41: Mo8Ga41 is a compound of endohedral gallide family and the compound of the highest critical temperature in the family. The highest critical temperature in this compound is a consequence of the competition between valence electron counts and the lattice structure variation. The high Tc of Mo8Ga41 is, in fact, a deviation from the rules proposed by Mathias in terms of electron counts. We found clear and direct evidence of two gap superconductivity in Mo8Ga41. The electron-phonon coupling in this system is found to be weak. The type II Dirac semimetal PdTe2: PdTe2 is known to be a material where topologically non-trivial bands and superconductivity co-exist. The recent observation of type II Dirac fermions in PdTe2 indicates the possibility of non-trivial Cooper-pairing when this compound undergoes superconducting transition below 1.75 K. We have shown that despite such unique coexistence, the superconducting phase is, in fact, conventional BCS type in nature [Ref. Shekhar Das et al., Phys. Rev. B 97, 014523 (2018)]. The superconducting phase in PdTe2 is further interesting because it also displays the distribution of critical fields on the surface where we observed domains of type I and type II superconductivity in the presence of magnetic fields. We show that such inhomogeneity in the superconducting phase is related to the electronic inhomogeneity in the normal state. A candidate topological superconductor Nbx-Bi2Se3: Bi2Se3 is a famous topological insulator. When Bi2Se3 is intercalated with elemental metals (e.g. Cu, Sr, and Nb) the resulting compound becomes superconductor with the critical temperatures of 3 K. Among all, NbxBi2Se3 (x = 0.25) is a stronger possible candidate for topological superconductivity. Here, through STM spectroscopy we show that the tunneling spectra deviate from a BCS-like behavior, and the tunneling conductance at low bias is large. Our results are in good agreement with the idea of topological superconductivity in Nbx-Bi2Se3. Tip-induced superconductivity in silicon: Surprisingly, when the STM tip makes metallic contact with the highly doped silicon crystal, a unique superconducting phase appears underneath the tip. The critical temperature of this phase was significantly higher (11 K). We employed Point-Contact Andreev Reflection (PCAR) spectroscopy for further investigation of superconducting phase in silicon and found that the superconductivity is conventional in nature which thoroughly follows BCS theory. To justify the above works, we have chosen the following thesis plan: Chapter I is an introduction to the work presented in this thesis. This thesis deals with the superconducting phase of topologically trivial as well as non-trivial systems. This chapter highlights the main key points of BCS theory of superconductors for conventional superconductors and the discussion of topological insulators, Dirac and Weyl semimetals. Chapter II describes the details of the experimental methods used to probe the superconducting phase of materials. The Scanning Tunneling Microscope (STM) is extensively used in most of the experiments in the work presented in this thesis. The experiments are carried out down to 300 mK temperatures with up to 11 T magnetic field. The sample preparation is done in-situ. Point Contact Andreev Reflection Spectroscopy (PCAR) is also employed in some of the experiments. All the experiments are carried out using a home-built point-contact probe down to 400 mK temperatures. A theoretical analysis part is also included in this chapter. The main experimental observations of my research work as discussed above have been included as a chapter III, IV, V and VI respectively. At the end of this thesis, I will be discussing some of the important works carried out by me and included in the appendices (A and B).
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