Title:	Investigation of superconductivity in candidate Dirac systems by ultra low temperature STM/S
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Abstract:	Abstract The transition metal dichalcogenides have recently received renewed atten- tion of the condensed matter physics community because a number of them have displayed topologically non-trivial band structures – often with Dirac-like bands with linear dispersion crossing the Fermi energy. Among the chalcogenides, it has been observed that the di-tellurides like $PdTe_2$, $MoTe_2$ and $Pt\text{-}IrTe_2$ not only host Dirac electrons, they also display superconductivity at extremely low temper- atures, and other system-dependent physical orders like ferroelectricity, CDW etc. at relatively higher temperatures. Such novel electronic properties of these mate- rial systems can be controlled by chemical doping, metal-ion intercalation, hydro- static pressure, electric and magnetic fields etc. This thesis primarily deals with the study of some of the aforementioned properties of a few doped/intercalated transition metal di-tellurides using an ultra-low temperature, ultra-high vacuum scanning tunnelling microscope (STM). Homogeneous type-II superconductivity in $PdTe_2$ upon Cu intercalation: Earlier it was shown that despite having Dirac electrons taking part in transport in the type-II Dirac semimetal $PdTe_2$, the superconducting phase (T_c □ 1.7 K) in the system is conventional in nature. This was surprising because owing to the coexistence of superconductivity and Dirac physics, it was thought that the system would display unconventional topological superconductivity. In terms of its magnetic properties, $PdTe_2$ remained interesting as the surface displayed a mixed type-I/type-II phase seemingly originating from intrinsic electronic inho- mogeneities. We have shown that upon intercalation of Cu between the layers of $PdTe_2$, the system becomes uniformly type-II with an enhancement of the transi- tion temperature (T_c) up to 2.4 K. Our measurements suggest that the enhance- ment is due to increased density of states at the Fermi energy contributed by the Cu intercalates. Conventional superconductivity in $Pt_{0.1}Ir_{0.9}Te_2$: In case of $PdTe_2$, it could be argued that the superconducting phase was conventional because multiple bands crossed the Fermi surface and only a few of them were topologically non-trivial 1and the conventional superconductivity might appear only in the trivial bands. We found a superconducting system, $Pt\text{-}IrTe_2$, where it is known that the bands that take part in transport are also topologically non-trivial (Dirac). In fact, with 10% Pt-doping, the Dirac point in this system comes very close to the Fermi energy. We have investigated the superconducting properties of the system and found sur- prising conventional superconductivity even in 10% Pt-doped $IrTe_2$. These ob- servations indicate that mere existence of Dirac electrons in a system does not guarantee the emergence of topological superconductivity. Unconventional superconductivity, CDW and piezoelectricity in $Re\text{-}MoTe_2$: In this context, we also investigated the Re doped Weyl semimetal $MoTe_2$ where a dramatic enhancement of the superconducting transition temperature (from 100 mK in pure $MoTe_2$) to 4.1 K was earlier observed upon Re-doping. We found that the enhanced superconducting phase leads to a dramatic enhancement of the up- per critical field that exceeds the Pauli paramagnetic limit. This observation shows that $Re\text{-}MoTe_2$ can be a potential system where the magnetic field does not destroy the superconducting phase through usual orbital pair breaking (through the for- mation of vortices), but suppresses superconductivity by Pauli paramagnetic pair breaking effects. Therefore, our results present $Re\text{-}MoTe_2$ as a potential system where hitherto elusive Fulde-Ferrel-Larkin-Ochnikov (FFLO) superconductivity with finite Cooper pair momentum and a spatially modulating order parameter can be realized. In addition to that, CDW and piezoelectricity in Re- $MoTe_2$ was also studied in detail. 2
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