Summary

Superconductivity has remained an active area of research for over 100 years. The interplay between superconductivity and other phases of matter continues to be an excellent avenue to explore novel physical phenomena. This thesis is a report on materials in which electrons form Cooper pairs and have symmetry properties that allow for the exhibition of novel phenomena in the superconducting state. The type-II Dirac semimetal $PdTe_2$ is a type-I superconductor with unusual superconductivity in the surface sheath. The results of relaxation calorimetry to investigate the intermediate state, and a pressure study as well as a doping study to tune the superconductivity, are presented here. The angle-dependent magnetotransport study on the layered superconductor $LaO_{0.8}F_{0.2}BiS_{2-x}Se_x$ ($x = 0.5$ and 1.0), with breaking of the local inversion symmetry possibly leading to the large anisotropy in the upper critical field is presented. The content of the chapters is as follows:

The first chapter served as a short introductory treatment on topological materials and superconductivity. The main purpose was to peak the interest of the reader by explaining why these phases of matter have garnered widespread interest. $PdTe_2$, the material which is the focus of this thesis, was introduced. The second chapter dealt with the experimental aspects used in the research that culminated in this thesis. The setups used to investigate material behaviour at low temperatures were given and described in detail. The third chapter introduces the relevant theoretical aspects to the later chapters.

In Chapter 4 the results of the heat capacity study on $PdTe_2$ using relaxation calorimetry were presented. The type-I nature of superconductivity was successfully probed by the observation of latent heat of the intermediate phase in fields, giving the first thermodynamic evidence for type-I superconductivity in $PdTe_2$. Weak-coupling was inferred from the zero-field jump size $\Delta C/\gamma T_c = 1.42$, exponential scaling in the low temperature range and the full superconducting temperature range being accurately captured by Mühlschlegel's tabulated values.

In Chapter 5 the study on the disorder-induced transition from type-I

to type-II superconductivity in $PdTe_2$ was presented. The goal was to intentionally induce disorder in $PdTe_2$ by the isoelectronic substitution of Pt to force the transition. Two single-crystalline batches $Pd_{1-x}Pt_xTe_2$ were prepared with nominal values $x = 0.05$ and $x = 0.10$. Sample characterization by EDX spectroscopy revealed Pt did not dissolve homogeneously in the crystals. The prepared samples could nonetheless sufficiently be characterised to attribute the transition to increasing disorder. By demonstrating the absence of the differential paramagnetic effect in ac susceptiblity measurements and the latent heat in heat capacity measurements for the $x = 0.10$ batch we have unambiguously presented evidence for the transition from type-I to type-II superconducting behaviour upon increasing disorder. In terms of the residual resistivity a minimum value of $\rho_0 = 1.4$ $\mu\Omega$cm suffices to turn $PdTe_2$ into a superconductor of the second kind.

In Chapter 6 the angle-dependent magnetotransport measurements on $LaO_{0.8}F_{0.2}BiS_{2-x}Se_x$ ($x = 0.5$ and 1.0) were shown. A large anisotropy in the angular variation of B_{c2} was observed with a large maximum value for $B \parallel ab$. The value of B_{c2} for $B \parallel ab$ exceeds the limits set by the orbital pair breaking and paramagnetic pair breaking effects. From measurements carried out at low temperatures it is inferred that the anisotropy in the superconducting state persists monotonously down to 0.3 K. Whether the anisotropy is of a 2D or a 3D nature can not be concluded from the current data-set. Local inversion symmetry breaking should manifest in these systems through Rashba-type spin-orbit coupling. This possibly leads to a significant suppression of the orbital and paramagnetic effects for B_{c2} allowing for the mediation of the large B_{c2} observed.

In Chapter 7 the details of a high pressure transport study of superconductivity in $PdTe_2$ were presented. The effect of pressures higher than reported previously on superconductivity are shown to have a monotonic decrease except for the observation of a sharp decrease around 2 GPa. Other measurements showed this decrease to be sample or run-specific as it was not reproducible, indicating a smooth monotonic decrease to be intrinsic behaviour of $PdTe_2$ under pressure. The superconductivity of the surface sheath was shown to persist at higher pressures as evidenced by the upturn around 5 mT and the differences in WHH plots between the $R = 0$ and onset temperature plots. No changes originating from the topological transitions of the Dirac cones predicted to occur around 4.6-6.1 GPa were observed.