Title:	Transport Spectroscopic Investigation of Anisotropic and Multiband Superconductors
Authors:	Datta, Soumya (/jspui/browse?type=author&value=Datta%2C+Soumya)
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Abstract:	This thesis will describe my studies on four superconducting materials; AuBe, RuB 2 , Ru 7 B 3 , and ZrB 12 where, for experimental purposes, primarily two trans- port spectroscopic methods were used; point-contact Andreev reflection spec- troscopy (PCARS) and scanning tunneling spectroscopy (STS). We found that the superconductivity in all these four materials, in one way or another, disagrees with a conventional, isotropic, single-gap BCS description. In AuBe and RuB 2 , two s-wave gaps are necessary to describe the quasiparticle excitation spectra at ultra-low temperatures. For AuBe, a simple two-gap model incorporating inter- band tunneling of quasiparticles seems sufficient. On the other hand, RuB 2 war- rants a more advanced model with additional factors like interband scattering. In Ru 7 B 3 , which is a non-centrosymmetric superconducting phase, unlike RuB 2 , we found that a small ‘p-wave’ component is necessary with the otherwise dominant ‘s-wave’ one in the description of the superconducting order parameter. While studying superconducting ZrB 12 , we observed two exciting features. On the ba- sis of directional PCARS and two-coils mutual inductance measurements, it was found that the superconducting gap and its local critical field are anisotropic in this material. From the same experiments, it was also found that ZrB 12 behaves like a type-I as well as a type-II superconductor depending on the direction of the applied magnetic field. These observations match remarkably well with the theoretical expectations for an anisotropic superconductor near critical B-point, which was proposed recently. The overall outline of the thesis is given below, where I plan to describe the results of my four projects in four successive chapters starting from third to sixth. Chapter 1: The relevant theoretical concepts related to the thesis will be discussed in this introductory chapter. This will include a brief discussion of conventional and unconventional superconductivity. Apart from that, different contexts of anisotropies in a superconductor and their possible origins, such as iunconventional pairings and multi-gap effects, will also be discussed. Chapter 2: This chapter will briefly describe the experimental methods used in this thesis. This will primarily include two transport spectroscopic methods; point contact Andreev reflection spectroscopy (PCARS) and scanning tunneling spectroscopy (STS). The advantage of directional PCARS will also be discussed. Chapter 3: In the third chapter, I will describe the results of our STS investi- gation on non-centrosymmetric superconductor AuBe. I will describe a comparison between a single-gap and a simple two-gap model for various spectra probed at different points on the sample surface. The analysis will also include the temper- ature and magnetic field dependence of one such typical spectrum. At the end of this chapter, I will also present the results of some theoretical calculations to support our claim. Chapter 4: This chapter will describe the results of our detailed STS investi- gation on another multi-gap superconductor, RuB 2 . I will highlight the indications of two gaps in this material from the previous report and I will show the spectral signature of the two gaps from our ULT STS measurements. In the end, I will highlight the shortcomings of a simple two-gap model and suggest some possible modifications in such a model to describe the data more accurately. Chapter 5: In the fifth chapter, I will describe our STS investigation on an- other non-centrosymmetric superconductor Ru 7 B 3 , where we found the signature of a small ‘p-wave’ component mixed with the dominant conventional ‘s-wave’ one in the superconducting order parameter. The appearance and disappearance of a ‘zero-bias conductance peak’ in the spectra with increasing temperature, a possible reason of which is the presence of higher-order symmetry in the order parameter, will also be discussed. I will relate our observations with some indications of un- conventional pairing from previous reports on Ru 7 B 3 . Chapter 6: I will begin this chapter with a discussion about intertype super- conductivity in the context of an anisotropic superconductor. Furthermore, I will iijustify why we choose ZrB 12 as a potential material system to explore anisotropic intertype superconductivity. I will point out the contradictions in various previ- ous reports, the limitations of previous PCARS studies in this material, and also highlight how those limitations can be overcome with a fresh direction-dependent PCARS study. Based on our detailed directional PCARS study and two-coil mu- tual inductance measurements, I will present clear proves of anisotropy and field direction-dependent type-I/type-II behavior in this system. Chapter 7: The seventh and last chapter of my thesis will provide a conclu- sive summary extracted from our investigations mentioned in the last four chapters.
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