

Preface

The epoch of high- T_c superconductivity began in 1986 when Bednorz and Muller found evidence for superconductivity at $T_c \sim 30$ K in La–Ba–Cu–O ceramics. This remarkable discovery has renewed the interest in superconductive research. The late discovery of superconductivity in rare earth transition metal borocarbides in 1994 is still an intensive debate with respect to unusual features not observed for conventional superconductors. In the 2001 year, the discovery of superconductivity in MgB_2 initiated an immediate broad research activity due to the high transition temperature $T_c \sim 40$ K in a seemingly ordinary $s - p$ metal. Apart from the high transition temperature of 40 K, two-band superconductivity was the other unexpected phenomenon in MgB_2 which attracts increasing attention. In fact, at present it appears that MgB_2 is the only superconductor with substantiated theoretical and experimental evidence for two-band superconductivity.

In 2008, the discovery of a new family of high critical temperature iron and arsenic superconductors (AsFe) marked a new major revolution in the world of superconductivity. The new compounds, which do not contain copper (Cu) but which have oxygen (O), fluor (F) or arsenic (As), and iron (Fe) will help scientists to solve some of the mysteries in the area of solid-state physics. These compounds reveal many properties similar to high- T_c cuprates, and at the same time superconducting state has multiband character, likewise, to nonmagnetic borocarbides and MgB_2 . Fortunately, the experimental investigations revealed a great variety of “exotic” physical properties in the above-presented compounds such as multiband and anisotropic effects in superconducting state. Detailed comparison of the available data for new class of superconductors, especially with the high- T_c cuprates, might be helpful to improve our present incompetent understanding of challenging novel members of the rich and rapidly growing family of superconductors.

This book deals with the new class of materials unconventional superconductors – cuprate compounds, borocarbides, magnesium diboride, and oxypnictides. It gives a systematic review of physical properties of novel superconductors. There is an increasing number of fundamental properties of these compounds which are relevant to future applications, opening new possibilities. The layout of this book consists of four chapters. Chapter 1 is devoted to the description of physical

properties of newly discovered superconductors: cuprate superconductors, borocarbides, magnesium diboride, oxypnictides. We present briefly crystal structure, electronic properties, and related theoretical models for each group of superconductors. Anisotropy and multiband effects are specially emphasized. Well-known and generally accepted results of computed Fermi surface of these compounds are presented. Results of order parameter symmetry investigations in these compounds are discussed.

Chapter 2 gives a generalization of Ginzburg–Landau (GL) theory to the case of multiband and anisotropic superconductors. It is noted that single-band GL calculations were found to be inadequate for describing the temperature dependence of fundamental physical properties of these compounds, while the two-gap model was found to be successfully applied to determine the temperature dependence of superconducting state parameters in bulk nonmagnetic borocarbides MgB_2 , $\text{LuNi}_2\text{B}_2\text{C}$, and $\text{YNi}_2\text{B}_2\text{C}$. Presence of two-order parameters and their coupling play a significant role in determining its temperature dependence. The results of the calculations are in good agreements with experimental data for bulk nonmagnetic borocarbides and magnesium diboride. We also conclude that the two-band GL theory explains the reduced magnitude of the specific heat jump and the small slope of the thermodynamic magnetic field at critical temperature in MgB_2 . It is shown that the relation between upper critical field and so-called surface critical field is similar to the case of single-band superconductors. Temperature dependence of surface critical field of two-band superconductors must give positive curvature. Quantization of magnetic flux in the case of two-band superconductors remains the same as in single-band superconductors. However, Little-Parks oscillations of T_c in two-band superconductors is different from one band case. The generalization of two-band GL theory to the case of layered anisotropy is presented. We have calculated anisotropy parameter of upper critical field H_{c2} and London penetration depth λ for magnesium diboride single crystals. The temperature-dependent anisotropy of upper critical field is shown, which is in agreement with the experimental data for MgB_2 and reveal opposite temperature tendency to anisotropy parameter of λ . Angular effects on the base two-band GL theory are also studied. Structure of single vortex in layered two-band superconductors is presented. Influence of dirty effects in two-band superconductors using GL approach is also included in this chapter.

Results of investigation of upper critical fields, single vortex of d -wave superconductors, and nonlinear magnetization in $d + s$ wave superconductors using d -wave version of GL theory are the scope of the Chap. 2. Very recent application of GL-like theory to cuprate superconductors for the calculation fundamental parameters is presented. Time-dependent two-band isotropic GL equations and corresponding $(d + s)$ -wave equations were applied for the study of vortex nucleation and dynamics effects. Briefly discussed is the very recent exciting discussion of 1.5 type superconductivity in literature. How we can introduce coexistence of superconductivity and antiferromagnetism in the framework of GL theory is also presented. Finally, application of GL equations to nanosize superconductors and possible new effects of vortex nucleation in mesoscopic superconductors is briefly discussed at the end of this chapter.

In Chap. 3, we have summarized a number of recent investigations of layered superconductors using the microscopic electron–phonon Eliashberg theory. The critical temperature of layered superconductors was calculated using this theory, and the influence of nonadiabaticity effects on the critical temperature was considered. In the calculation of the effect of Coulomb repulsion on the critical temperature, arbitrary thicknesses of conducting layers were also taken into account. In the same approach, expression for the plasmon spectrum of layered superconductors with arbitrary thicknesses of the conducting layers was obtained. In addition, Bardeen–Cooper–Schrieffer (BCS) equations for layered superconductors were used for calculating the specific heat jump, which is smaller than in the isotropic case. The results are shown to be in qualitative agreement with experimental data for cuprate superconductors and the recently discovered MgB_2 compound.

Properties of two-band superconductors in isotropic (BCS) theory are investigated. The critical temperature, specific heat and upper critical field, influence of impurity, and doping effects on these parameters in two-band isotrop superconductors are considered. For the general outstanding nature of superconductivity in cuprates briefly presented results of d -wave BCS theory. The influence of nonadiabatic effects in two-band strong coupling superconductors is taken into account. Calculation of the spectrum of collective Leggett mode in two-band superconductors and related experimental data is included in Chap. 3. Finally, nanosize two-band superconductors in framework of BCS theory and related results are considered.

The last chapter of the book, Chap. 4, is devoted to fluctuation effects in new superconductors. There is an excellent book of Larkin and Varlamov about manifestation of fluctuation in isotropic and strong anisotropic superconductors. Here we study the fluctuation effects on specific heat in two-band superconductors taking the influence of external magnetic field into account. Diamagnetic susceptibility and fluctuation of conductivity neat T_c are calculated using two-band GL theory in application to new superconductors. Fluctuation of phase effects in layered superconductors on T_c studied using Lawrence–Doniach functional. Influence of post Gaussian fluctuation in superconductors is also considered. Finally, we present generalized GL theory for layered superconductors with small coherence lenght.

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