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Analytical solutions of the microscopic two-band theory for the temperature dependence of the upper critical fields of pure MgB_2 compared with experimental data

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Main theoretical results of the microscopic two-band theory for the temperature dependence of the upper critical fields $H_{c2}(ab)$ and $H_{c2}(c)$ in pure two-band systems like MgB_2 are presented. The analytical solutions for the upper critical fields near the superconducting transition temperature and near the zero temperature were transformed to be directly compared with experimental data. The experimental $H_{c2}(ab)$ and $H_{c2}(c)$ temperature dependences of textured MgB_2 films near the superconducting transition temperature were measured and compared with the respective theoretical formulas. The results of this theoretical approach were also compared with earlier published experimental data of other authors. The chosen method allows obtaining an accurate match between the theoretical expressions and experimental results.

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1. Introduction

The discovery of the high temperature superconductivity in the intermetallic compound MgB_2 (with the critical temperature $T_c \sim 39$ K) led to an intensive use of a two-band model proposed by Moskalenko [1] and independently by Shul *et al*. [2].

This model assumes the existence of an overlap of various energy bands on the Fermi surface and, consequently, of the anisotropy of the electron energy spectrum, inherent in real superconducting systems. After publication of [1] and [2] a new line of research appeared, namely, the determination of the physical properties of two-band (or multiband) superconductors. Moldavian physicists headed by V. Moskalenko have brought a significant contribution to the development of this research direction. Many books and a lot of articles concerning this problem were published. Let us mention some publications related to the history of multiband superconductivity: books [3–6] reviews [7–9], and articles [10–12]. These works contain the names of scientists from various countries who have contributed to the development of the theory of two-band superconductivity. In particular, let us take note of reviews [13–15]. We can see from the above mentioned links that a lot of studies had been carried out long before the discovery of high temperature superconductivity and, moreover, before the discovery of superconductivity in MgB_2. The two-band theory of superconductivity can explain many anomalies of the physical properties of real superconductors (see, for example, [3,8,9]) and it can be regarded as a classical theory. It is obvious that for any application it needs to be clarified, developed and generalized. It can be also applied for the case of MgB_2, which can be considered as a two-band anisotropic superconductor, because the energy spectrum of the electrons in this compound is anisotropic, namely, there are two different energy bands on the Fermi surface: one band (σ-band) is two-dimensional, while the other band (π-band) is three-dimensional, which leads to the appearance of additional peculiarities in a number of physical characteristics of this compound (see [16–18]).

It is impossible to refer to all theoretical and experimental works that were carried out in order to determine the physical properties of MgB_2. Let us note, in particular, that a two-band model with the variable density of charge carriers leads to a good agreement with experimental data for the thermodynamic and magnetic properties of MgB_2 while replacing Mg and B with other elements of the periodic table [19,20].