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Comparison of the upper critical fields obtained within Ginzburg-Landau and Werthamer – Helfand – Hohenberg theories for optimally-doped $YBa_2Cu_3O_{7-\delta}$ thin films

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Till today, there is still no comprehensive theory that could fully describe high-temperature superconductors (HTSCs). One may agree that is the most actual challenge in modern solid-state physics. Among HTSCs with a superconducting (SC) transition temperature T_c exceeding the boiling point of liquid nitrogen, scientists distinguish a class of metal oxides with an active plane CuO_2 such as $YBa_2Cu_3O_{7-\delta}$ (or YBCO), called cuprates. These type-II superconductors are known to have a strong *d*-wave anisotropy expressed in a low density of charge carriers, strong electronic correlations and quasi-two-dimensionality, according to a great number of studies [1, 2, 3, 4].
The high value of T_c results in short size of Cooper pairs determined by the coherence length. Depending on the given direction in a crystal lattice, the corresponding sizes of Cooper pairs in *ab*-plane ξ_{ab} are of an order of magnitude greater than ones along *c*-axis ξ_c. To determine $\xi_{ab}(T)$ and $\xi_c(T)$ coherence lengths, one needs to obtain preferably wide temperature dependences of the upper critical field $H_{c2}(T)$ in orientations of applied magnetic field both parallel to the *ab*-plane and *c*-axis.
We report in detail the comparison of the upper critical fields $H_{c2}(T)$ obtained within Ginzburg-Landau (GL) and Werthamer – Helfand – Hohenberg (WHH) theories for optimally-doped $YBa_2Cu_3O_{7-d}$ thin films. For different orientations of the magnetic field, the calculations give 638 and 153 T for $\mu_0 H_{c2}(0)$ || *ab* and $\mu_0 H_{c2}(0)$ || *c*, respectively, using WHH theory. The GL theory is able to describe experiment giving much higher values of $\mu_0 H_{c2}(0)$. For the first time, we obtained the temperature dependences of coherence lengths $\xi_{ab}(T)$ and $\xi_c(T)$ within proposed theories as well as using 50% and 90% criteria of the normal state resistivity value. The WHH($0.9\rho_N$) approach gives $\xi_{ab}(0)$ = 14.7 Å and $\xi_c(0)$ = 3.5 Å which correlates with literature data.

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