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Unravelling the magnetic properties of $Fe_{0.5}TeSe_{0.5}$ superconductor using Ginzburg–Landau (GL) formulation

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Abstract
The Gibbs free energy of the magnetic superconductor $FeTe_{0.5}Se_{0.5}$ has been analyzed in conjunction with the Werthamer–Helfand–Hohenberg (WHH) equation at a critical temperature (Tc) of 12 K. This study presents the temperature dependence of the upper critical magnetic field (Hc_2), coherence length (ξ_{GL}), penetration depth (λ_{GL}), and critical current density (Jc) of the $FeTe_{0.5}Se_{0.5}$superconductor. Using experimentally obtained values, phase diagrams were constructed, showing that Hc_2, ξ_{GL}, λ_{GL}, and Jc exhibit non-linear temperature dependence and approach zero as T approaches Tc. The large values of the Ginzburg–Landau (GL) characteristic parameters indicate that $FeTe_{0.5}Se_{0.5}$is a strongly type-II superconductor. The results obtained in this work are in good agreement with previous experimental findings on $FeTe_{0.5}Se_{0.5}$ superconductor.

Keywords Iron based superconductors (IBS), Upper critical field, Coherence length, Penetration depth and critical current density

1 Introduction

Superconductivity and magnetism deemed to be poles apart as magnetic fields typically destroy superconducting state are now studied together in many cases.The discovery of $LaFeAsO_{1-x}F_x$, exhibiting a superconducting transition temperature of up to 26 K uniquely combines magnetic iron with superconductivity, thus inviting a significant scientific attention [1]. The highest superconducting transition temperature (T_c) measured at ambient pressure in bulk iron based superconductors (IBS) is 43 K which is higher than that of some cuprates, such as optionally doped $La_{2-x}Sr_xCuO_4$ [2]. Different phases of iron-based superconductors are discovered which include $Ba_{1-x}K_xFe_2As$, the "122-phase" with T_c of ~ 38 K, $Li_{1-x}FeAs$, so-called "111-phase" with Tc = 18 K and FeSe, so-called "11-phase" with Tc = 8 K [3–5]. The superconducting transition temperature has increased up to ~ 55 K by replacing or substituting/doping of La with other rare earth elements such as, Ce, Sm, Nd, Pr, Gd, Eu and Tm wherein the obtained phase is called "1111-phase" These discoveries have greatly advanced the field of superconductors,