Orissa Journal of Physics
ISSN 0974-8202

Vol. 27, No.1
February 2020
pp. 43-48

Anisotropy of Sommerfeld coefficient in $SmFeAsO_{1-x}F_x$ (x = 0.15) Single crystal

A PATTANAIK[1], G PUROHIT[2*], and P NAYAK[2]

1 Department of Physics, IGIT Sarang, Odisha
[2] School of Physics, Sambalpur University, JV, Burla, Odisha
E-mail: geetanjolly@gmail.com

Received: 15.11.2019 ; Revised : 16.12.2019 ; Accepted :17.1.2020

Abstract : Magnetic field dependence of Sommerfeld coefficient in the superconducting system of $SmFeAsO_{1-x}F_x$ (x=0.15) single crystal studied by using modified Phenomenological Ginzburg Landau (GL) theory of multiband superconductors. Following which the anisotropic ratio of Sommerfeld coefficient (Γ) calculated as 7.91. This theoretical result is found to be very close to the experimental result of the same system. This analysis manifests that the proposed model can successfully be used for explaining anisotropy of multiband superconducting systems.

Keywords: Fe based superconductors, single crystal, Thermodynamic properties, Phenomenological G.L. theory.

PACS: 74.25.Dw, 74.25.Bt, 74.70.Dd

1. Introduction

After the discovery of superconductivity with transition temperature of 26 K in LaFeAsO, superconductor, a large number of materials fabricated with some common crystal structure along with the presence of FeAs (or FeSe, Te) planes. Besides this, the maximum value of transition temperature achieved in Sm and Gd-based superconductors. The higher values of transition temperature with respect to symmetry, order parameter, pairing mechanism, spin fluctuation and band structure are obtained in many of the superconducting systems [1, 2]. Out of these strong parameters, multiband superconductivity has played an important role during the fabrication of different superconductors. Along with this FeAs based high temperature superconductor with composition of $ReFeAsO_{1-x}F_x$ with rare earth R = Sm, Ce, Nd, Pr, Gd, Tb and Dy has initiated enormous interest because of some of its unique characteristics like high quality single crystal, availability of the multiple substitution sites and simplicity of crystal structure. Iron oxy pnictide superconductors have offered the supplementary compositional variation compared to cuprate superconductors. FeAs layers play the same role in iron pnictides as CuO_2 plays in cuprate superconductors [3].

Here we present theoretically single crystal specific heat anomaly for determining Sommerfeld coefficient by using modified Ginzburg-Landau (GL) theory applicable to multiband system. Here particularly, for $SmFeAsO_{1-x}F_x$ (x = 0.15), the analysis were made and anisotropic ratio of Sommerfeld coefficient (Γ) calculated.

2. Phenomenological GL-Theory

High temperature superconductors (HTSCs) are exceptionally type-II superconductors with GL parameter of the order of 10^2. Considering the Phenomenological mass tensor in to account, the anisotropic properties of HTSCs has been tried to observe with the correlation between anisotropic London equation as well as GL equation. It is worth to mention here that GL equation can be approximately used to observe the vortex state for low applied magnetic fields in the London limit and temperature close to superconducting transition temperature (T_c). Using anisotropic formulation, the change in specific heat has been derived earlier [3-5] and found to be successful in different single band superconducting systems. Again for two band system we have also modified the change in specific heat earlier [6, 7] and is given by

$$\langle \Delta C \rangle = \left[B_a T / (T_c)^2 \right] \left[\alpha \; \Theta(\gamma) / \lambda_m^2(0) \right] \quad (1)$$

For two energy gaps existing in the system one has to split the equation considering two critical temperatures T_{c1} and T_{c2} as energy gap is directly proportional to the critical temperature and the segregated equations be obtained as mentioned earlier papers as [6, 7]

$$\langle \Delta C\rangle = \left[B_a T/(T_{c1})^2\right]\left[\alpha\ \Theta(\gamma)/\lambda_{m1}^2(0)\right] \tag{2}$$

$$\langle \Delta C\rangle = \left[B_a T/(T_{c2})^2\right]\left[\alpha\ \Theta(\gamma)/\lambda_{m2}^2(0)\right] \tag{3}$$

$$\Delta C = \Omega\left(B_a\right)T \tag{4}$$

Besides the above, other notations have usual meaning. Here $\Omega\left(B_a\right)$ represents Sommerfeld coefficient. Comparing equations (1) and (2) with equation (4), we may write the two equations as depending on two directions of applied field i.e. parallel and perpendicular to c-axis.

$$\Omega_1\left(B_a\right) = \frac{B_a}{T_{c1}^{\ 2}\lambda_{m1}^{\ 2}(0)} \tag{5}$$

$$\Omega_2\left(B_a\right) = \frac{B_a}{T_{c2}^{\ 2}\lambda_{m2}^{\ 2}(0)} \tag{6}$$

3. Results and discussions

It has been reported earlier by Welp et.al. [8] about the behavior of specific heat and upper critical field in a single crystal of $SmFeAsO_{1-x}F_x$ (x = 0.15) with a transition temperature of 49.5 K. Systematic studies on the $SmFeAsO_{1-x}F_x$ superconductor through the point-contact Andreev-reflection (PCAR) spectroscopy show an evidence of two-gap superconductivity with the gap values ratio 3 [9]. This gives T_{c1} and T_{c2} as 49.5K and 16.5 K respectively. GL equation in the form of equation (1) is used for interpreting observations of variation of specific heat with temperature for different applied fields. The liner regression has been made for applied fields in both orientations having field strength of 2, 4, 6 and 7.9 T respectively. The square root of inverse of each slope of the linear regression for a given applied magnetic field gives value of mean penetration depth. Ultimately, for field parallel to *ab*-plane or field parallel to *c*-axis we got the value of penetration depths as. The similar process has been carried out for both critical temperatures. A sample curve of linear regression of change in specific heat with temperature is shown in figure-1. By using the values of penetration depths (λ_{c1}, λ_{ab1} & λ_{c2}, λ_{ab2}) for different values of applied field in equations (5) and (6), we got the values of Sommerfeld coefficient $\Omega_1(B_a)$ and $\Omega_2(B_a)$ respectively. The variation of Sommerfeld coefficient ($\Omega_{c1}(B_a)$, $\Omega_{c2}(B_a)$ & $\Omega_{ab1}(B_a),\Omega_{ab2}(B_a)$) with different values of applied field and their orientations has been shown in figures 2 and 3 respectively. It has been seen that variation of both Sommerfeld coefficient with applied field increases slowly for small fields. The anisotropic ratio Γ $(=\Omega_c(B_a)/\Omega_{ab}(B_a))$ has been calculated for each transition temperature and total anisotropic ratio calculated. Here, we found it to be 7.91 as comparison to the experimental result of 8 in this particular system [8].

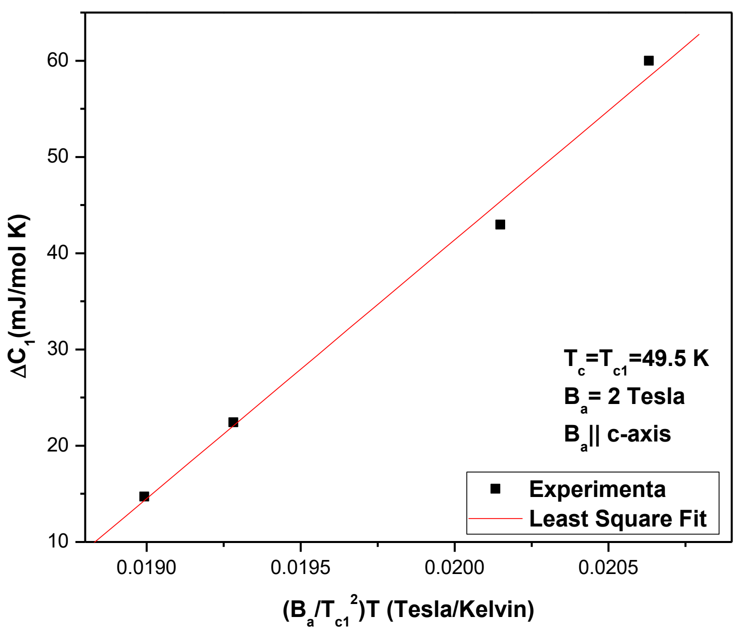

Fig. 1: (Sample curve of regression for T_{c1} at applied field parallel to c- axis)

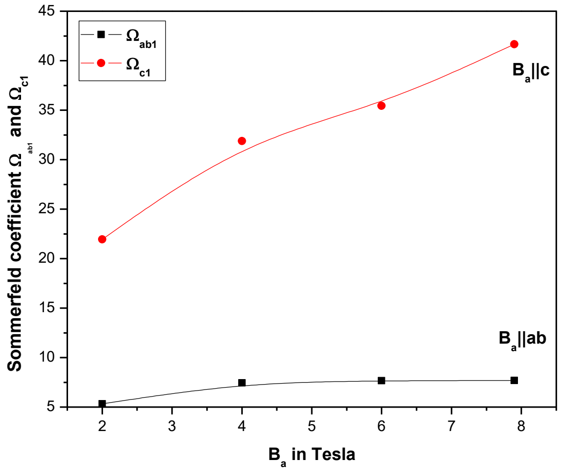

Fig. 2: Variation of Sommerfeld coefficient ~ applied field at T_{c1} in both orientations

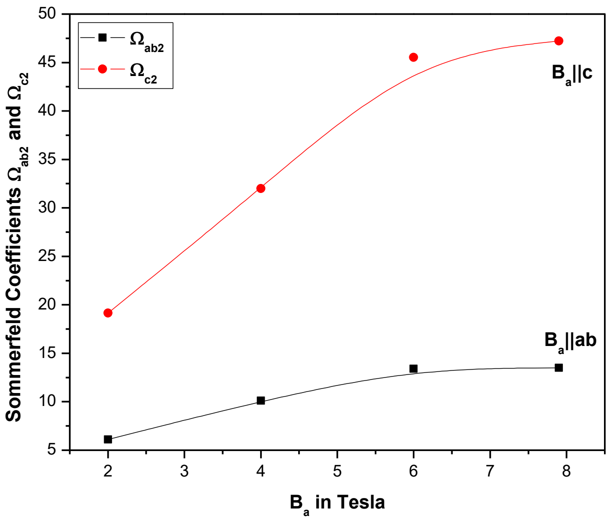

Fig. 3: Variation of Sommerfeld coefficient ~ applied field at T_{c2} in both orientations

4. Conclusion

In this work we have tried to explain the experimental observation related to change in specific heat theoretically by using Phenomenological GL theory. In doing so we evaluated the value of Sommerfeld Coefficient anisotropic ratio as 7.91 for $SmFeAsO_{1-x}F_x$ (x = 0.15) single crystal which is very close to the experimental value obtained earlier.

References

[1] U Welp et al., *Phys. Rev. B* **78**, 140510 (R) (2008)

[2] Y Jia et al., *Applied Physics Letters* **93**, 032503 (2008)

[3] A. Pattanaik et al., *Physica B* **405** 3234 (2010) and references therein.

[4] L J Campbell, M M Doria, V G Kogan *Phys. Rev. B* **38**, 2439 (1988)

[5] V G Kogan, M M Fang and S Mitra, *Phys. Rev. B* **162-164**, 1689 (1989)

[6] G Purohit and P Nayak, *J Supercond Nov Magn.* **29**, 1279 (2016)

[7] G Purohit, A Pattanaik, P Nayak, *Eur. Phys. J. B*, **91**, 9 (2018)

[8] U Welp et al., *Phys Rev. B* **83**, 100513 (2011)