2D Lowest Landau Level Scaling in $FeTe_{0.5}Se_{0.5}$

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Swati Pandya, L. S. Sharath Chandra, Siya Sherif, and V. Ganesan

2D Lowest Landau Level Scaling in $FeTe_{0.5}Se_{0.5}$

Swati Pandya[*], L.S. Sharath Chandra[*+], Siya Sherif[†*] and V. Ganesan [* #]

[*]*UGC-DAE Consortium for scientific research, University Campus, Khandwa Road,Indore (MP) 452017*
[+]*Presently at Materials, Advanced Accelerator Science Division, Raja Ramanna Centre for Advanced Technology, Indore -452 013*
[†]*Department of Studies in Physics, University of Mysore, Manasagangothri, Mysore -570 006*

Abstract. Magneto resistivity of $FeSe_{0.5}Te_{0.5}$ is investigated. Zero field resistivity shows onset of superconductivity at ~14 K. Zero field and magnetic field induced fluctuation conductivity has been analyzed in light of Aslamozov-Larkin (AL) and Lowest Landau Level (LLL) theories. Zero field fluctuation conductivity shows 2D nature in a narrow temperature range just above the mean field T_C, which is further supported by 2D LLL scaling observed for applied fields larger than ~8T for $FeTe_{0.5}Se_{0.5}$.

Keywords: Iron Chalcogenides, Fluctuation conductivity, Lowest Landau level.
PACS: 74.70.Xa, 74.40.-n, 71.70.Di

INTRODUCTION

Superconductivity in the class of new Fe based materials is unexpected because most of the Fe based compounds exhibit strong magnetic behavior. In recent times FeTe has been observed to be superconducting under chemical pressure [1]. It is found that the Se doping at the site of Te for FeTe induces chemical pressure which gives rise to the superconductivity [1, 2]. $FeTe_{1-x}Se_x$ shows maximum T_C for x ~ 0.5 [2]. Study of thermal fluctuations and nature of dimensionality in superconductors is very important, as it gives clue for its efficiency in applications. In this paper, we have investigated the zero field and magnetic field induced fluctuation conductivity of the $FeTe_{0.5}Se_{0.5}$ superconductor using Aslamozov-Larkin (AL) theory and lowest Landau level (LLL) scaling respectively to understand dimensionality of the system.

EXPERIMENTAL DETAILS

Polycrystalline $FeTe_{0.5}Se_{0.5}$ samples are prepared using a solid state reaction method. The samples were characterized by X-ray diffraction using CuK_{α} radiation in a Rigaku diffractometer. The resistivity is measured down to 2K and up to 14T magnetic field with conventional four probes using a Quantum Design Physical Property Measurement System.

RESULTS AND DISCUSSIONS

X-ray diffraction shows that sample is formed in tetragonal P4/nmm structure with small amount of magnetic impurity i.e Fe_3O_4 and Fe_7Se_8, like previously reported results. Resistivity of $FeTe_{0.5}Se_{0.5}$ shows semi-conducting to metallic crossover around ~150K and onset of superconductivity at ~14K. The obtained mean field T_C from dρ/dT is 12.8K. The zero field superconducting transition FWHM width obtained from dρ/dT is around 1K but the tail of superconducting transition below mean field T_C is quite broad. Application of magnetic field shifts the transition to lower temperature and makes it more broaden. The application of 14T shifts the mean field T_C at ~10.5K.

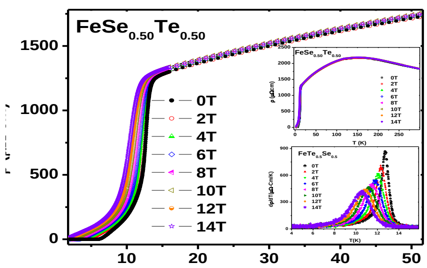

Fig 1. Resistivity in presence of field upto 14T for $FeTe_{0.5}Se_{0.5}$. Insert shows the resistivity in temperature range 2-300K and derivative of resistivity in different fields.

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To study the fluctuation dimensionality, zero field fluctuation conductivity above T_C is analyzed by Aslamozov-Larkin (AL) theory, using a microscopic approach in the mean field region where the fluctuations are small and expressed as: $\Delta\sigma = A\varepsilon^{\alpha}$, where $\Delta\sigma$ is excess conductivity , ε is the $\ln(T/T_C)$, A is the temperature independent amplitude and α is the conductivity exponent [3] . $\Delta\sigma$ in zero field as a function of **ε** are shown in fig (2). We observed the 2D behavior $(\Delta\sigma)_{2D}$ α ε^{-1} near the transition temperature i.e 13 K to 13.2 K for $FeTe_{0.5}Se_{0.5}$. Following the similar procedure reported in ref.3, ξ_C is estimated from zero field fluctuations in a narrow region, where the 3D fluctuations are expected turns out to be ~ 0.3 Å, which is very small as compared to lattice parameter along c-axis, indicates 2D nature of fluctuations in $FeTe_{0.5}Se_{0.5}$.

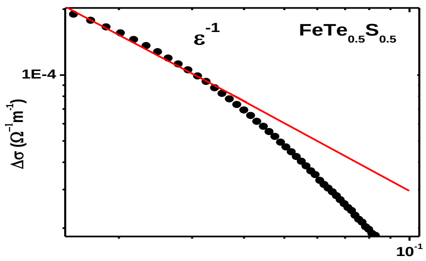

Fig 2. The variation on the excess conductivity ($\Delta\sigma$) versus $\ln(T/T_C)$ plot for $FeTe_{0.5}Se_{0.5}$.

The superconducting fluctuations in presence of magnetic field are analyzed using the Lowest Landau Level (LLL) scaling [3, 4]. In a strong magnetic field the paired quasi particles are effectively limited to being in their lowest Landau level, the superconducting fluctuations in bulk low T_C as well as in high T_C materials acquire an effective one-dimensional (1D) character along the field direction. This reduction of the effective dimensionality increases the importance of fluctuations, resulting in a fluctuation region around $T_C(H)$ [3]. There exists a scaling law for excess conductivity ($\Delta\sigma$) due to fluctuations in magnetic fields in terms of unspecified scaling functions F_{2D} and F_{3D}, valid for 2D and 3D cases, respectively, [3, 4]

$$\Delta\sigma (H)_{2D} = (T/H)^{1/2} F_{2D} (A [(T-T_c(H)) / (TH)^{1/2}])$$

$$\Delta\sigma (H)_{3D} = (T^2/H)^{1/3} F_{3D} (B [(T-T_c(H)) / (TH)^{2/3}])$$

Similar scaling has been applied to $FeTe_{1-x}S_x$ chalcogenides and 2D nature of fluctuations is confirmed [3]. In order to verify the nature of fluctuations in this system , we plot $\Delta\sigma (H/T)^{1/2}$ versus $[(T-T_c(H)) / (TH)^{1/2}]$ for 2D scaling and $\Delta\sigma (H^{1/3}/T^{2/3})$ versus $[(T-T_c(H)) / (TH)^{2/3}]$ for 3D LLL scaling for $FeTe_{0.5}Se_{0.5}$, which are shown in fig(3) . The same plots in semilogarithmic scale are shown in inset of fig 3. The temperature interval is same for 2D and 3D scaling. Data of 2D scaling collapse on same curve above 8T, which indicates 2D scaling is better than the 3D scaling in a narrow temperature range just above the mean field T_C for magnetic field > 8T for $FeTe_{0.5}Se_{0.5}$.

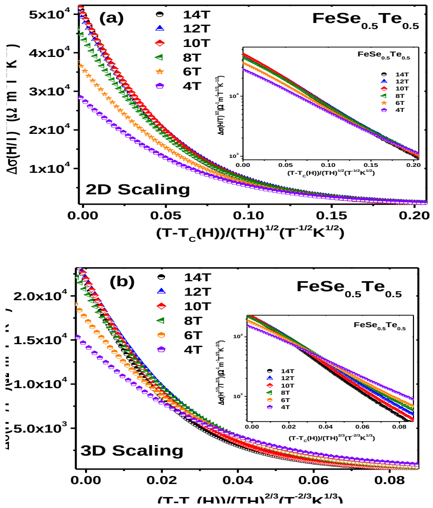

Fig 3. (a) 2D and (b) 3D LLL scaling for $FeTe_{0.5}Se_{0.5}$ for magnetic field upto 14T. In the insets, same plots are shown in semi-logarithmic scale.

In conclusion, The coherence length estimations indicate 2D nature of superconductivity in the $FeTe_{0.5}S_{0.5}$.This result is further supported by observation of 2D nature of fluctuations in zero fields in a narrow temperature range near transition and by magnetic field fluctuation conductivity above T_C (H), which shows a clear 2D lowest Landau level scaling for fields above $\mu_0 H_{LLL}$ ~8T for $FeTe_{0.5}Se_{0.5}$.

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