

Hydrostatic Pressure Studies on Parent Phase SrFBiS₂ of BiS₂-based Superconducting Family

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Recently discovered BiS₂-based layered superconductors have gained tremendous interest in the scientific community. These BiS₂-based superconductors have superconducting transition temperature (T_c) as 4.5K for Bi₄O₄S₃ [1,2], 2-5K for REO/FBiS₂ (La, Ce, Pr, Nd) [3-6] and 2.8K for Sr_{0.5}La_{0.5}F_{0.5}BiS₂ [7]. It is interesting to note that their parent phases LaOBiS₂ [3] and SrFBiS₂ [8] are semiconducting, which upon the O/F doping in former [3-6] and Sr/RE doping in later [7] become superconducting. Superconducting transition temperature in REO_{0.5}F_{0.5}BiS₂ RE (La, Ce, Pr, Nd) is observed to increase under the hydrostatic pressure by three fold just in 2GPa pressure [9-14]. It is suggested that this dramatic increase in T_c is related to a structural phase transition under pressure especially for LaO_{0.5}F_{0.5}BiS₂ as reported by Tomita et.al [13]. Recently, we found that the T_c of Sr_{0.5}La_{0.5}F_{0.5}BiS₂ superconductor increased by fivefold from around 2K to above 10K, accompanied by the semiconducting to metallic normal state [15]. Keeping in view, that application of hydrostatic pressure has resulted in tremendous increase of T_c for the BiS₂ based superconductors [9-15], one wonders how their non-superconducting parent compounds will respond to the same. In the present work, we measure the temperature dependent electrical resistivity from 300K down to 2K under applied hydrostatic pressure (0-2.5GPa) for SrFBiS₂, which is the parent compound for the BiS₂-based superconductors [8].

In this study, the polycrystalline SrFBiS₂ sample was synthesized by the standard solid state reaction route via vacuum encapsulation. Stoichiometric ratio of Sr, SrF₂, Bi, and S were ground thoroughly in Ar-controlled glove box before palletized. Rectangular pellets were vacuum sealed (10^{-3} Torr) in quartz ampoules and heat treated at 780°C for 12h at heating rate of 2°C/min with an intermediate grinding. X-ray diffraction (XRD) was performed at room temperature in the scattering angular (2θ) range of 10°-80° in equal 2θ step of 0.02° using Rigaku Diffractometer with Cu K_{α} ($\lambda = 1.54\text{\AA}$). Rietveld analysis was performed using the standard FullProf program. The obtained phase pure samples were used for pressure dependent resistivity measurements by Physical Property Measurements System (PPMS-14T, Quantum Design) where pressure applied by HPC-33 Piston type pressure cell with Quantum design DC resistivity Option. Hydrostatic pressures were generated by a BeCu/NiCrAl clamped

piston-cylinder cell. The sample was immersed in a fluid (Daphne Oil) pressure transmitting medium in a Teflon cell. Annealed Pt wires were affixed to gold-sputtered contact surfaces on each sample with silver epoxy in a standard four-wire configuration.

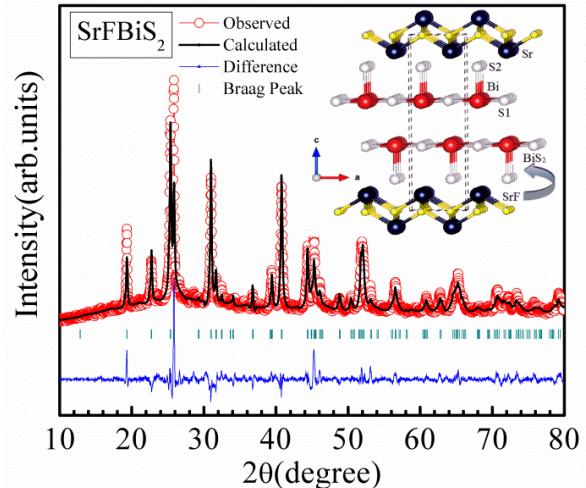


Figure 1 (Color online). Room temperature Reitveld fitted XRD pattern of SrFBiS₂

The room temperature observed and Reitveld fitted XRD pattern of SrFBiS₂ compound is shown in the figure 1. The SrFBiS₂ crystallized in tetragonal structure with space group $P4/nmm$. The estimated parameters are $a=4.08(3)\text{\AA}$ and $c=13.78(2)\text{\AA}$ as obtained from minimizing difference between the observed and calculated patterns, which are in confirmation with earlier report [8]. Inset of the figure 1 is the unit cell of the SrFBiS₂ compound.

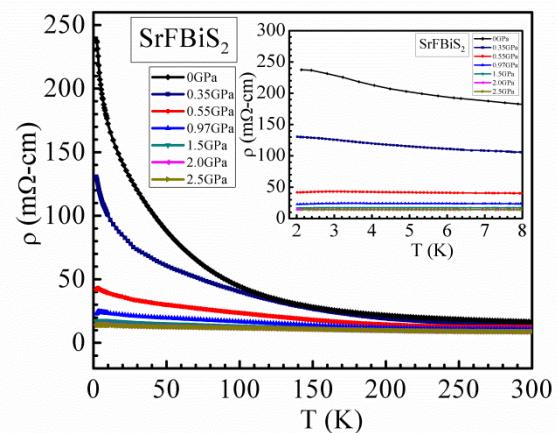


Figure 2 (Color online) Temperature (T) dependences of resistivity (ρ) under hydrostatic pressure for SrFBiS₂ and the inset is the extended part of the same from 2K-8K.

Figure 2 shows the temperature dependence of electrical resistivity under the different hydrostatic pressure (0-2.5GPa) for SrFBiS₂ down to 2K. A clear semiconducting behavior can be observed in the temperature range 300-2K as temperature coefficient

$d\rho/dT < 0$ is negative. With increasing applied pressure the electrical resistivity decreases significantly. At the applied pressures of 2.17 and 2.5GPa the electrical resistivity becomes almost temperature independent. The inset of the figure 2 shows the zoomed portion of same in the temperature range 8K to 2K. There is no indication of superconducting transition down to 2K under maximum applied pressure of 2.5GPa. Though the suppression of resistivity in SrFBiS₂ under hydrostatic pressure is similar to the as for other BiS₂-based layered superconductors viz., LaO_{0.5}F_{0.5}BiS₂ and Sr_{0.5}La_{0.5}FBiS₂, but did not show superconductivity down to 2K under applied pressure of 2.5GPa. The absolute ρ value at 2K is two orders of magnitude less than as in ref. 7 and even four orders lower than as in ref.8. This may happen due to the volatility of Bi, S and F in these compounds [7,8], and is in fact debatable.

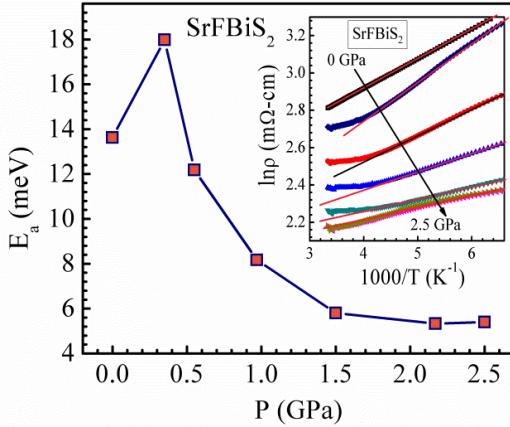


Figure 3 (Color online) Pressure dependence of activation energy (E_a), being evaluated from thermal activation equation; the solid line is a guide to eye. Inset is the $\ln(\rho)$ Vs $1/T$ for the different pressures (0-2.5GPa) for SrFBiS₂; the solid lines are the extrapolation to the fitted portion.

Figure 3 presents the thermal activation energy (E_a) as a function of applied hydrostatic pressure as obtained from fitting of the resistivity data to the equation $\rho(T)=\rho_0 \exp(E_a/k_B T)$ above 100K. Except for 0.35GPa, the thermal activation energy drops exponentially with pressure. Inset of the figure 3 is the plot of $\ln(\rho)$ Vs $1/T$ to evaluate the activation energy of SrFBiS₂ from 0-2.5GPa pressure. It is interesting to note that the value of ρ_0 under different hydrostatic pressures remains almost same close to 7.2mΩ·cm. This observation suggests that at highest temperature the resistivity of sample is almost constant even under different hydrostatic pressures. The activation energy decreases with increasing pressure and saturates close to 5.3meV. This suggests that the Fermi energy moves close to conduction band by increasing pressure, while the highest temperature resistivity remains constant. Detailed spectroscopic and theoretical investigations

with and without pressure are warranted to validate this point on recently discovered SrFBiS₂ compound.

In summary, the temperature dependence of resistivity suggests that the activation energy for one of the parent compound of BiS₂-based superconductor SrFBiS₂ decreases under applied pressure. Further, superconductivity could not be induced down to 2K under applied pressure of as high as 2.5GPa.

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