Intrinsic magnetic effects in $LaO_{0.5}F_{0.5}BiS_2$ from magnetic susceptibility and NMR measurements

Silverio Delgado, Shrishti Yadav, Lei Shu (Fudan University), Dr. Oscar Bernal
Department of Physics and Astronomy, California State University, Los Angeles

Funding source:
Research at CSU-LA is supported by NSF/PREM DMR-1523588; at Fudan U. by Chinese NSF-1147060, at UCSD by NSF DMR-1206553 and US DOE DEFG02-04ER46105. NSF-HRD CREST 1547723.

INTRODUCTION

We present magnetic susceptibility and NMR data in $LaO_{0.5}F_{0.5}BiS_2$ that suggest intrinsic magnetic effects in the normal state of this material. Magnetization measurements in temperatures from 2.7 K to 300 K and applied fields from -8 T to 8 T, and NMR experiments are compared to estimate the intrinsic magnetic contribution to the magnetic effects observed by both techniques. With the aid of Palladium (Pd) metal as a standard to assure that our equipment is operating accurately, our analysis of the data indicates that besides the expected contribution from paramagnetic impurities in the starting materials, there exists an intrinsic susceptibility whose origin is still not fully determined. The results clarify that we do observe an interesting magnetic phenomenon in $LaO_{0.5}F_{0.5}BiS_2$, potentially related to a Rashba or a Dresselhaus effect that has been predicted for the parent compound.

DIAGRAM OF $LaO_{0.5}F_{0.5}BiS_2$

- In previous research[1] it was found that $LaO_{0.5}F_{0.5}BiS_2$ is a superconducting material with a crystal structure of stacked BiS_2 superconducting layers, as shown in figure 1. Lanthanum atom sheets act as blocking layers for the BiS_2 superconducting planes where the carriers (provided by LaOF atoms) reside.
- Superconducting properties appear between 2.7K and 10K depending on whether the samples are produced at ambient or high pressure respectively.
- None of the component elements of the system is intrinsically magnetic, the parent compound is a diamagnetic insulator.

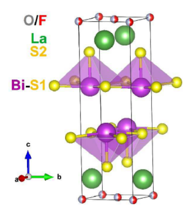
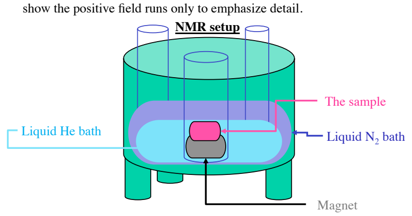


Figure 1: $LaO_{0.5}F_{0.5}BiS_2$ crystal structure is represented in a molecular diagram. The Solid line is an indication of how the samples unit cell would be broken down.[2]

METHOD

- In a PPMS VSM apparatus from Quatum Design, the sample was Zero-Field cooled and data were recorded upon warming up in field from 3 K and up.
- Then the sample was field cooled from 300K down to 2.7K and data were recorded as the sample cooled.
- Sample was then warmed up again in field and data were again recorded from 2.7K to 300K.
- Constant magnetic field runs were taken in fields from -80 kOe to 80 kOe. We here show the positive field runs only to emphasize detail.



RESULTS

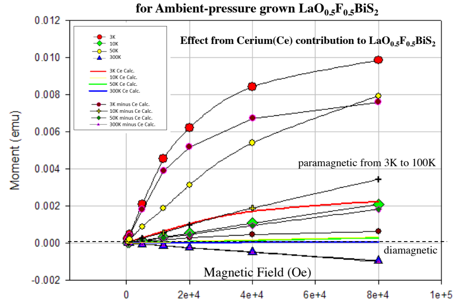


Figure 2. The magnetization as a function of applied field, the magnetic moment will saturate at low enough temperatures and high enough fields. Paramagnetic impurity content was tested for and found to be significant for Cerium; in the amount of 180 ppm per weight. Contributions to the magnetization by this amount of paramagnetic centers were calculated and subtracted from the total magnetization.

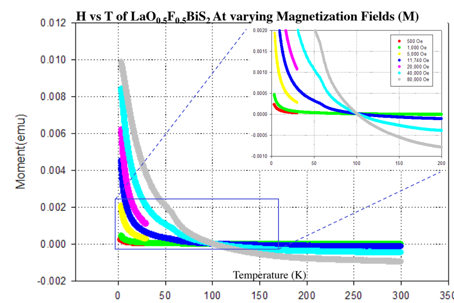


Figure 3: Temperature dependence of the magnetization at different applied fields. The sample is diamagnetic above 100 K for most fields and paramagnetic below 100 K for all fields tried. Note that the data shows a bump at 50 K for all fields

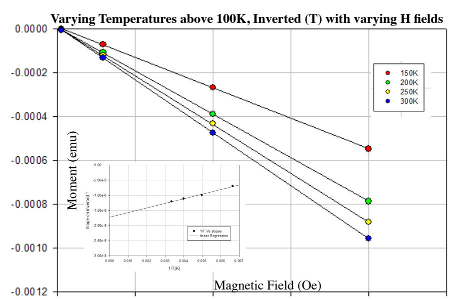


Figure 4: The slopes from varying temperatures as functions of applied field, show that the Magnetic moment will plateau at high enough T. As the temperatures increase the slopes do converge to the same value. That intercept is -1.724e-8 emu, Which is then divided by its mass of 0.16275 grams to get -1.0593e-7 emu/gram

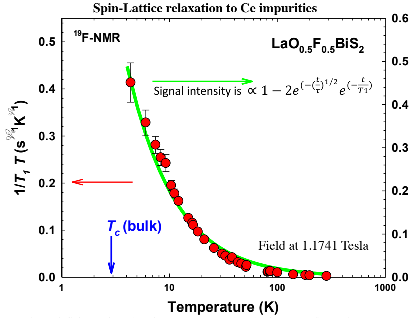


Figure 5: Spin-Lattice relaxation rates were analyzed using a two-fluctuating sources model: Ce paramagnetic impurities and intrinsic magnetic degrees of freedom w/unknown nature. Formula used to fit two source of relaxation times T1(Ce impurities) and Tau(intrinsic Magnetic fluctuations). 1/(T1*T) follows the magnetization of the impurities at all temperatures

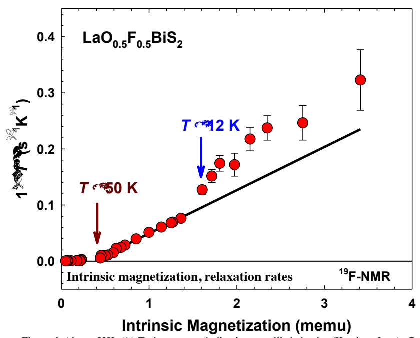


Figure 6: Above 50K, $(1/\tau T)$ is constant, indicating metallic behavior (Korringa Law). Between 12 and 50 K the relaxation is linear with respect to the intrinsic magnetization; direct correlation b/w electronic magnetism and nuclear response. Below 12 K, there's an excess of relaxation rate above and beyond the underlying electronic magnetic polarization.

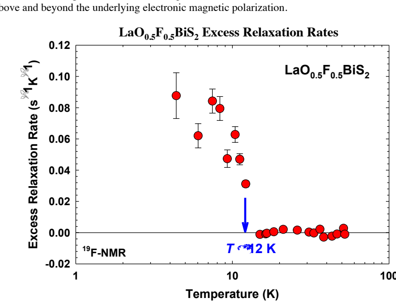


Figure 7: Excess relaxation rate can be extracted and becomes an "order" parameter for the local state (superconductivity?); fluctuations are independent from and coexist with the intrinsic magnetization. Rashba/Dresselhaus effect does not require charge carriers and can exist in the insulating parent compound. Whereas the doped system has excess charge in the conduction band therefore coexistence of these two independent phenomena might be expected as coming from different electronic bands.

ANALYSIS

- Magnetization measurements revealed 3 sources; 2 paramagnetic and 1 diamagnetic, with one of the paramagnetic sources attributed to Ce impurities.
- NMR measurements are consistent with the same two kinds of paramagnetic sources found in the magnetization.
- The measurements show that the sample is *paramagnetic* even though none of the individual chemical elements in it are.
- The spin/lattice relaxation contribution from Ce centers behaves typically, whereas the relaxation contributed by the intrinsic paramagnetism is anomalous: linear in magnetization below 50 K and strongly enhanced starting below about 12 K
- The excess magnetization below 12 K develops as a kind of order parameter, indicating a change of microscopic state below this temperature.

SUMMARY AND CONCLUSIONS

- We have measured the magnetic susceptibility of $LaO_{0.5}F_{0.5}BiS_2$ and the spin-lattice relaxation time in the normal state.
- We find that the system has intrinsic diamagnetic and paramagnetic contributions to the magnetization.
- The coincidence of the relaxation enhancement with the temperature at which some samples display superconductivity might indicate that the new state sampled here is that of superconducting fluctuations.

FUTURE Research…

- As an electron- doped system this material has excess charge in the conduction band. As a non-centrosymmetric crystal it allows for strong spin/orbit coupling in the valence band. Therefore coexistence of phenomena related to these two independent electronic states (superconductivity and magnetism) can be expected.
- If true, the above conclusion motivates the search for applications in fields such as "spintronics," which is a new way of controlling spin transport and magnetic field storage.
- Understanding the nature of this relaxation mechanism and its coexistence w/magnetic degrees of freedom might lead to new device application, charge & spin carriers in the same device.

ACKNOWLEDGEMENTS

Would like to thank the outstanding professor of the year, Dr. Bernal for giving me a chance to work with him and his group I would also thank Shrishti Yadav allowing me to shadow her in the lab and get a great understanding of samples behavior. Big thanks to PREM and NSF for the opportunity and funding. Thanks to CSULA Physics and Astronomy department.

References:

1)Superconductivity in Novel BiS_2 -Based Layered Superconductor LaO 1Àx Fx BiS_2 Mizuguchi, Yoshikazu, Demura, Satoshi,Deguchi, Keita,Takano, Yoshihiko,Fujihisa, Hiroshi,Gotoh, Yoshito,Izawa, Hiroki,Miura, Osuke
2)In-plane charge fluctuations in bismuth-sulfide superconductors Athauda, Anushika,Yang, Junjie,Lee, Seunghun,Mizuguchi, Yoshikazu,Deguchi, Keita,Takano, Yoshihiko,Miura, Osuke,Louca, Despina