Probing the Putative Neutral Fermi Surface of SmB_6 Using Specific Heat

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Introduction

There has been much debate as to whether or not the de-Haas van Alphen oscillations seen in SmB_6 result from metallic surface states or bulk insulating states, the latter of which corresponds to a Femi surface of charge-neutral excitations[1-4]. This debate is based on SmB_6 exhibiting quantum oscillations (QOs) in magnetization but not in the resistivity up to 93T. One way to shed light on the true origin of these QOs would be to measure the magnetic field dependence of the specific heat for stoichiometric and non-stoichiometric samples, since it is a bulk probe of the total density of states and less susceptible to extrinsic effects than magnetization.

Experimental

A custom single axis rotatable micro-calorimeter employing the ac-calorimetric method was used to obtain the first set of high field heat capacity (*C)* and magnetocaloric measurements on SmB_6. Measurements were performed in the 31 T, 50 mm bore, top-loading cryostat (cell 9) at the NHMFL in Tallahassee Florida.

Results and Discussion

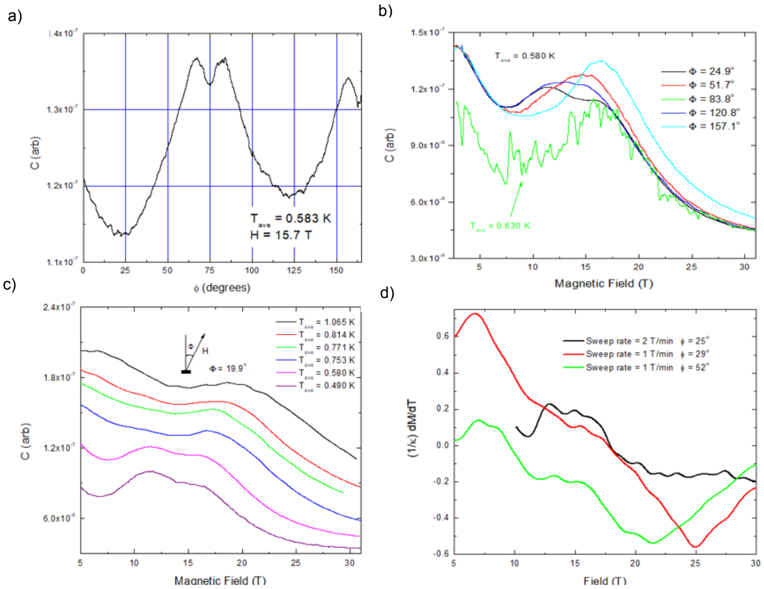

Figure 1: a) Heat capacity vs angle at T = 0.583 K, H = 15.7 T b) Heat capacity vs field at select angles relative to the applied field c) Heat capacity vs field for select temperatures at a fixed angle of 19.9^{o} d) Magnetocaloric effect vs field for different sweep rates and angles at a fixed temperature T = 0.583 K.

In the first experiments, we found an asymmetric dependence of the heat capacity about ~ 90^{o} with respect to angle upon rotating the sample over a 180^{o} range in a constant field of H = 15.7 T as seen in Fig.#1a). Here the angle Φ is between the field and the flat face of the sample. The field dependence of *C* at the extrema is shown in Fig.#1b). Here we see a broad peak around 17 T and the emergence of a second broad peak around 12 T for angles Φ ~ 10-30^{o}. The broad peak centered about the partial ordering field, H_m = 17 T, has a maximum that is angle and temperature dependent as shown in Fig.#1b) & c) respectively. A second peak, centered around 12 T, appears at low angles. The temperature and field dependence of these broad features were then investigated at Φ = 19.9^{o}, the angle shown to provide the best definition of the two features as seen in Fig.#1c). Here we find an emergent second feature seen for Φ = 19.9^{o} upon cooling from *T* ~ 1.0-0.5 K. Temperature dependence shows a downshift in H_m and sharpening of the main feature upon cooling. The second peak emerges between 0.753-0.580 K and appears to become larger and sharper at lower temperatures. Magnetocaloric (*MC*) studies, which yield a quantity proportional to d*M*/d*T* where *M* is the magnetization, were also performed at fixed angles and sweep rates, as shown in Fig.#1d). Apparently, a distinct change is observed in d*M*/d*T* near 18T, the source of which presents an additional puzzle. A naive interpretation would assign this behavior to crossover between antiferromagnetic and paramagnetic behavior, but no such phases are known for SmB_6. We also see a sharp angle and field dependent feature of unknown origin between 20 and 25 T. Our main observation, however, is the lack of discernible heat capacity QOs in the same *H* and *T* region as dHvA QOs are observed. More work will be needed to establish the existence of a true null result.

Acknowledgements

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References

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