Determining the Fermi Surface of Colossal Magnetoresistive Materials

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Introduction

The rare earth manganites have been the subject of a high level of research activity for many years [1]. Their rich temperature/doping phase diagram, strongly-correlated properties and the colossal magnetoresistance (CMR) that they display have made them extremely important materials in the field of condensed matter physics and are of interest to theoreticians and experimentalists alike. Despite all this attention many questions still remain, especially regarding the origin of the ferromagnetic, CMR phase. Having an unprecedentedly high response to external stimuli, this phase is of great significance to technologists for use in actuators and other electronic devices. In particular, the Fermi surface has yet to be satisfactorily mapped out. Positron annihilation experiments have been successful in some manganites [2,3], but magnetic quantum oscillations (QOs), the most established and reliable method for determining the bulk Fermi surface, have yet to be observed in these materials.

Experimental

Single crystal samples of $La_{1-x}Sr_xMnO_3$ and the bilayer manganites $La_{2-2x}Sr_{1+2x}Mn_2O_7$, and $La_{2-2x}Nd_{2-2x}Sr_{1+2x}Mn_2O_7$, at different values of *x*, were mounted for quantum oscillation measurements in the 100 T magnet at NHMFL, LANL. Two different experimental techniques were utilized. In the first, the samples were placed in the pick-up coil of a compensated-coil magnetometer, which is optimized for de Haas-van Alphen measurements. The second technique involves 6 to 8-turn coils wrapped around the samples. These coils are used as the inductive part of an LCR circuit driven by a proximity detector oscillator at frequencies close to 40 MHz. The frequency at which the circuit oscillates is known follow changes in the skin-depth of the material inside the coil, and hence is sensitive to Shubnikov-de Haas oscillations [4]. Both ^{4}He and ^{3}He cryostats were used and measurements took place in temperatures below 2 K.

Results and Discussion

In both experiments a large signal was observed at low fields due to the alignment of ferromagnetic domains. The magnetic-field dependent data from the highest field regions were Fourier transformed. At the lowest temperatures this revealed a number of consistent peaks in the frequency region below 5000 T. The positions of the peaks depend systematically on sample composition. There are also systematic differences between dHvA (magnetization) and PDO (transport) data that could help in identifying the nature of the Fermi-surface orbits.

Conclusions

The results are promising. Further measurements are warranted. In particular, based on recent precedents in the cuprates, traditional four-contact transport measurements could lead to an increase in signal-to-noise for the oscillating part of the data. Samples are being prepared.

Acknowledgements

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References

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