Quantum oscillations in the high pressure metallised Mott insulator NiS_2

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Introduction

The electronic structure in the correlated state near a Mott metal-insulator transition can be examined in the nickel pyrite NiS_2, which metallises at moderate applied pressures. We have grown single crystals of NiS_2 with residual resistivities of less than 1 $\mu\Omega$cm in the metallic state above 3GPa. In order to optimise signal to noise performance in anvil cell high pressure measurements, we have combined a microcoil in the sample space with a tank circuit oscillator circuit. This enables us to observe quantum oscillations by tracking the tank circuit resonance frequency, and in high-pressure NiS_2 we have previously resolved oscillations at a frequency of about 6kT [1]. DFT calculations attribute this frequency to a large, cubic hole pocket in the center of the Brillouin zone, with significantly renormalised carrier mass. The main objective of the March and August 2017 experiments was to extend these measurements to higher pressure, in order to follow the evolution of the effective carrier mass as the sample is tuned further away from Mott localisation.

Experimental

A microcoil with a diameter of <0.3 mm is located in the gasket hole of a miniature diamond anvil pressure cell. A Van Degrift-type tunnel diode oscillator was mounted near the pressure cell on a low temperature insert. Wiring the microcoil as the tank circuit inductance, we have obtained stable oscillations in the range 250-450 MHz. Measurements were performed at NHMFL in a top loading dilution refrigerator in cell 8 in 3/2017 and in a ^{3}He system in cell 9 in 8/2017.

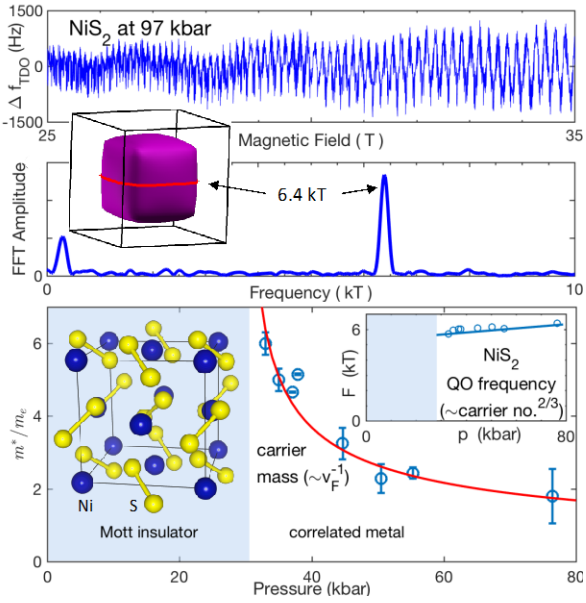

Figure 1: High pressure quantum oscillation data in NiS_2 obtained with the tunnel-diode oscillator technique (top panel), and preliminary analysis of the pressure dependence of carrier mass and quantum oscillation frequency (bottom panel). The inset of the top panel shows the shape of the Fermi surface sheet corresponding to the 6.4 kT oscillation as obtained from DFT calculations (see also June 2017 NHMFL Science Highlight.)

Results and Discussion

Quantum oscillations at frequencies near 6 kT were observed clearly at a number of pressures ranging from 76 kbar to 115 kbar, and a rotation study was carried out at 86kbar. The newly available data enables a closer look at the pressure dependence of Fermi surface size and carrier mass (Fig. 1).

Conclusions

Quantum oscillations have been detected in pressure metallised NiS_2 up to pressures of almost 120 kbar. This demonstrates that detailed electronic structure measurements can be extended into pressure regimes which were previously considered out of reach. This represents a big step towards resolving the nature of the correlated electronic state on the threshold of Mott localisation in high pressure NiS_2, and it motivates similar studies in other materials in which the electronic excitation spectrum under high pressure is of interest.

Acknowledgements

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References

[1] S. Friedemann *et al.* Large Fermi Surface of Heavy Electrons at the Border of Mott Insulating State in NiS_2 *Scientific Reports* **6,** 25335 (2016).