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 $\mu$Î©m in the metallic state above 3 GPa. 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 6 kT [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.

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 86 kbar. 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.

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References