Quantum Oscillations in Pnictides and 1-1-5’s

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Introduction
In order to understand the mechanism of superconductivity in pnictides and the 1-1-5 the knowledge of the Fermi surface topology in these multiband superconductors is a prerequisite. In particular topological changes upon elemental substitution may give valuable information on the importance of certain bands for the superconducting state. During our project, we studied CeFe$_2$P$_2$, which is a non-superconducting rare earth variant of the K$_{1-x}$Ba$_x$Fe$_2$As$_2$ of superconductor. In addition we measured the quantum oscillations in the superconducting Rh variant BaRh$_2$P$_2$ of this structure, which has a critical temperature T$_c$ of 1.0 K. We also started to investigate LuCoIn$_5$, which is the hole equivalent of LaCoIn$_5$ in an attempt to get an experimental handle on the long-standing question in the physics of heavy fermions of what seems to drive the difference between electrons (CeCoIn$_5$ is a superconducting HF) and holes (YbCoIn$_5$ is a “light” paramagnetic metal) within the same crystallographic structure.

Experimental
Preliminary measurements in a superconducting magnet showed that high fields and low temperatures as provided by the 35 T and a 3He setup at the NHMFL DC facilities are needed to obtain sizable oscillations. We used a torque magnetometer setup mounted on a rotator platform to measure the angular dependence of the de Haas-van Alphen (dHvA) oscillations.

Results and Discussion
For CeFe$_2$P$_2$, we took measurements rotating within the ac-plane, a plane, which is perpendicular to the FeP layers. There we observed signatures of strongly corrugated Fermi cylinders. The existence of Fermi cylinders is a direct evidence of 2D Fermi surfaces (FS), which are a consequence of the layered structure, while the strong corrugation indicates a considerable coupling between the layers and the notion towards three dimensionality of the Fermi surface. The investigated compounds are somewhere between 2D and 3D metals which leads to small yet finite anisotropies of their properties such as resistance or critical fields [1]. Additionally observed oscillations frequencies evidence the existence of truly 3D FS as suggested by band structure calculations.

From the temperature dependence of the dHvA oscillations we were able to determine the band selective effective mass at some distinct orientations. The mass enhancement was approximately a factor 2, which was also found for other compounds of the same family (see e.g. [2]).

In BaRh$_2$P$_2$ we were able to follow the dHvA signals for rotating from the a-axis to the c-axis, as well as from the [110] to the c-direction.

In the 1-1-5 compound we mapped the Fermi surface by rotating from the crystallographic a to the c-axis and determined the band selective effective masses for one of the orientations.

Conclusions
Our results indicate that the difference in the physical properties of the pnictides might originate from rather subtle differences in the shape of the Fermi surface.

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References