Large Volume High Pressure Cell for Pulsed Field Studies

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Introduction

Pressure studies add the capability to smoothly tune energy scales in a material, allowing, for example, the scientist to induce superconductivity, explore properties near quantum critical points, and develop a picture of the Fermi surface.

Experimental

Our group has developed plastic diamond anvil cells (DAC) capable of pressures to 3.5 GPa for use in pulsed magnetic fields, but the small sample volume (Ø0.3 mm x 0.06 mm) makes the experiment challenging. As part of a collaboration with NHMFL LANL, we have successfully tested a large volume (Ø2 mm x 1.5 mm) miniature piston-cylinder cell capable of 2 GPa in the 60 T LP. Although metallic, modeling performed at LANL clearly showed that there was sufficient thermal lag to acquire reliable data in the 60 T long pulse magnet before the eddy current heating of the cell reached the sample. Sophisticated electronics and data analysis have also been developed to acquire SdH quantum oscillations at He-3 temperatures using the tunnel diode oscillator (TDO) technique. A rotator was recently added to the probe so that complete fermiology studies could be carried out. The pressure cell technology has been spun off to NHMFL LANL so that they can support users.

Results and Discussion

Data on Cr (fig. 1) clearly shows no sample heating with the amplitude of the quantum oscillations in Cr being the same during the up and downsweep for the lowest achievable temperatures. Although the signal to noise is better in comparable data taken in a DAC, this is most likely due to the compensated coil configuration used for the feasibility study of the piston-cylinder cell.

Conclusions

This new capability provides the opportunity to explore P, B, T phase space to 60 T with a clear design path to higher fields. Up to six electrical leads can be introduced into the sample space permitting dHvA, SdH via TDO or PDO, and transport studies such as Hall Effect and magnetorestance. Optical access provided by fiber optics make possible PL, PLE, photoconductivity, and dilatometry via fiber Bragg grating studies, a project proposed several years ago, which holds great promise in providing access to another thermodynamic variable.

Acknowledgements

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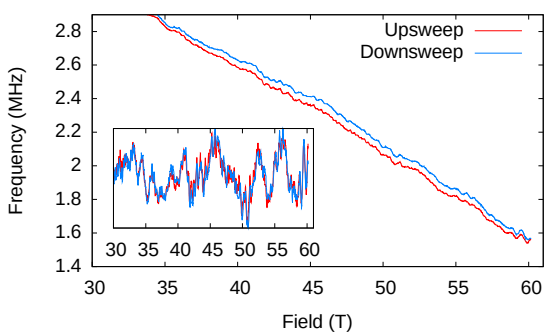

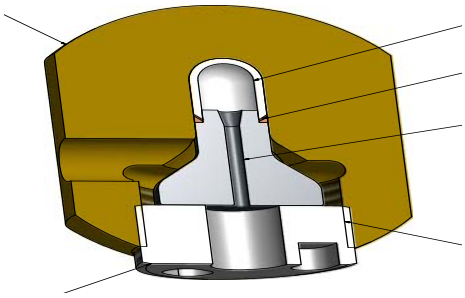

Fig.1 Cr SdH data taken via TDO at T=1.2K and P=0.2 GPa in the 60 T long pulse magnet showing clear evidence that the sample temperature remains constant throughout the pulse. Figure 2 Miniature piston-cylinder cell (mini-me) used for the study. The body of the cell and the clamp nut are made from MP35N and the piston is made from a nonmagnetic WC. The Teflon cup and pressure medium provide the necessary thermal lag to allow studies to 400 mK without eddy current heating from the body and nut reaching the sample prior to completion of the pulse.