Angle Dependence of Shubnikov-de Haas Effect of $NdOs_4Sb_{12}$

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Introduction

The rare-earth filled skutterudite compound $NdOs_4Sb_{12}$ is a ~ 1 K ferromagnet, which exhibits mean-field ferromagnetism (FM) [1]. As inferred from specific heat measurements, the electronic specific heat coefficient γ of this compound is enormous (~ 520 mJ/mol-K^2), which may arise from the existence of a low-lying excitation. Previous ultrasonic measurements by Yanagisawa *et al.* show an additional ultrasonic attenuation and dispersion in $NdOs_4Sb_{12}$ and $SmOs_4Sb_{12}$ at ~ 15 K [2] besides the regular dispersion near ~50 K. In addition, recent study of the Nd substation in the $Pr_{1-x}Nd_xOs_4Sb_{12}$ system shows coexistence of FM and superconductivity [3]and recent muon spin relaxation abnormal suppression of the Nd moments, origin of which is still unclear [4]. Therefore, the investigation of the Fermi-surface of $NdOs_4Sb_{12}$ will help in illuminating the origin of large γ , additional ultrasonic dispersion in $NdOs_4Sb_{12}$ and effect of Nd substitution on the unconventional superconductivity of $PrOs_4Sb_{12}$.

Experimental

Single crystals of the filled skutterudite compound $NdOs_4Sb_{12}$ were prepared by the molten metal flux method at UCSD. The angle dependence of the MHz skin-depth measurements of single crystals of $NdOs_4Sb_{12}$ were measured for temperatures down to ~ 1.3 K and magnetic fields up to 60 tesla in the Pulsed Field Facility at NHMFL/LANL.

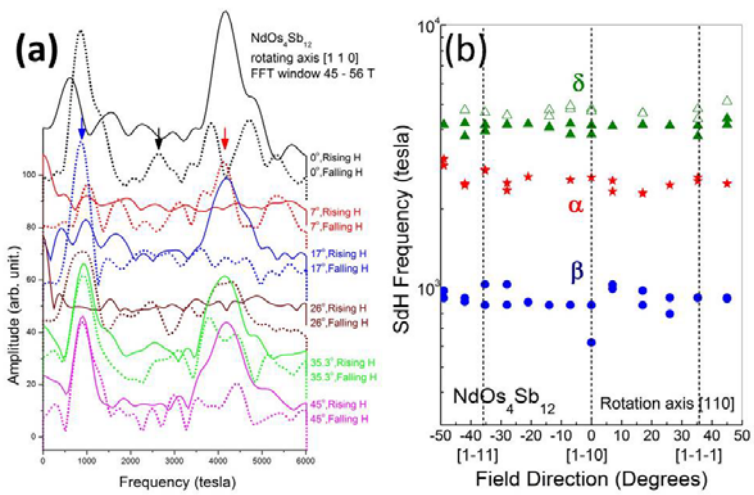

Fig. 1 (a) SdHos amplitude vs frequency of $NdOs_4Sb_{12}$ detected at ~1.3 K at various rotating angles of magnetic field with respect to the crystalline axis [110]. (b) Determined SdH frequencies as a function of the magnetic field direction with respect to crystalline direction [1-10] and rotating about [110].

Results and Discussion

Displayed in Fig. 1 (a) are the Shubnikov de Haas oscillation (SdHos) amplitudes as a function of frequency measured on high quality single crystals of $NdOs_4Sb_{12}$. The magnetic field *H* is rotating about the crystalline axis [110] from -49° to 45° with respect to the [1-10] direction, which is equivalent the direction of *H* changing from [1-11] (i.e., -35.26°) to [1-1-1] (i.e., 35.26°). Three SdHos frequencies are detected 903±88, 2580±210, and 4100±170 tesla (shown in Fig. 1 (b)), the first two of which agree with the dHvA and SdH oscillation branches β and α detected previously along the high symmetry axes [5]. The 4100-tesla branch labeled as δ is newly detected in this experiment.

Conclusions

Two branches of the Fermi surfaces (α and β) detected in the angle dependence of the SdHos experiments for *H* rotating about the crystalline direction [110] in $NdOs_4Sb_{12}$ are comparable to those of $PrOs_4Sb_{12}$ [6]. A new branch of Fermi surfaces at ~ 4100 tesla was detected in this experiment.

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References

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