Heat Capacity and Elastic Constants of Single Crystal Niobium


Introduction

Niobium is a body-centered cubic (bcc) transition metal with only one naturally occurring isotope. It has the highest superconducting transition temperature among the elements at ambient pressure. Several reports have noted anomalies in crystalline Nb in the elastic constants [1, 2], but no work to our knowledge has discovered anomalous behavior in the specific heat. We present in this report specific heat and elastic constants on the same high-quality crystal of reactor-grade Nb. The results presented are preliminary.

Experimental

The Nb crystal was prepared by repeated Electron Beam Melting (EBM) and annealing in Ultra High Vacuum at Escola de Engenharia de Lorena - USP. The resulting crystal was oriented by back scatter Laue diffraction. The elastic constants were obtained by Resonant Ultrasound (RUS) using the NHMFL RUS Flow Cryostat. Heat capacity was obtained from the Heat Capacity Flow Cryostat. Heat capacity data were verified at Montana State University using a Quantum Design Physical Properties Measurement System (PPMS). All data were collected at ambient magnetic field.

Results and Discussion

Preliminary results for the C44 (shear mode) elastic constant are presented in Fig. 1. Results for C11 and C12 show no apparent anomalies and are not presented. The shear mode does show an anomalous softening on cooling from T ~ 280 K to T ~ 200 K before resuming normal behavior. The results presented need further analysis and are not final. The discontinuity at T ~ 260 K is an experimental artifact. The specific heat data (Fig. 2) show an unexpected, and to our knowledge, never previously observed anomaly approximately coincident with the minimum in C44. This sharp spike in the specific heat of single crystal Nb (~ 5 K FWHM) is of unknown origin, but its existence has been confirmed by multiple measurements at the NHMFL, and by measurement at MSU using a PPMS. No other reproducible anomalies in the specific heat of our sample (other than the superconducting to normal phase transition) are observed in the temperature range studied (2 K < T < 350 K).

Conclusions

We have observed anomalous behavior in the heat capacity and C44 elastic constant of single crystal Nb. Further study of this system will be required to establish the origin of these anomalies.

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References