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Research and technical note

Specific heat of stainless steel below $T = 1$ K

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The specific heat of 304 stainless steel has been measured in the temperature range 70–600 mK. A Schottky anomaly has been found and the data can be represented by $C(T) = (465T + 0.56T^{-2})$ μJ g^{-1} K^{-1}. This large specific heat can lead to long thermal relaxation times in low temperature apparatus, especially below 100 mK.

Keywords: stainless steel; specific heat; Schottky anomaly

Stainless steels are employed frequently in the construction of low temperature apparatus. An adiabatic demagnetization refrigerator (ADR)[1,2] designed for cooling infrared bolometers below $T = 100$ mK on a spacecraft uses type 304 stainless steel (ss). This material was chosen as a reliable non-corrosive container for the paramagnetic salt. This ADR is cycled at $T = 1.5$ K, adiabatically demagnetized to its operating temperature of ≈ 100 mK and then isothermally demagnetized to maintain this temperature for many hours. The entropy change required to cool the thin-walled ss salt pill container was not critical, but ss contributed significantly to the thermal time constant of ≈ 1 min of the cold stage below 1 K. A short internal time constant is important for high duty cycles and for stable temperature regulation.

Experiment and results

We measured the heat capacity of 304 ss between 70 and 600 mK using a relaxation technique[3]. The 128 mg sample was suspended with brass wires from the temperature regulated ADR cold stage. Two small neutron transmutation doped Ge thermometers[4] with different doping levels were glued to the surface and calibrated with a commerical GRT (model GR-200A-30, Lake Shore Cryotronics, OH, USA). A thin film chip heater (from Minisystems, MA, USA) was also attached. The Ge thermometers were current biased and the voltages read out with cold JFETs (Infrared Labs, AZ, USA). The thermal conductance G of the suspension wires was measured by dissipating a known amount of power in the heater and measuring ΔT. Thermal time constants were measured by switching off the heater power and recording the voltage as a function of time.

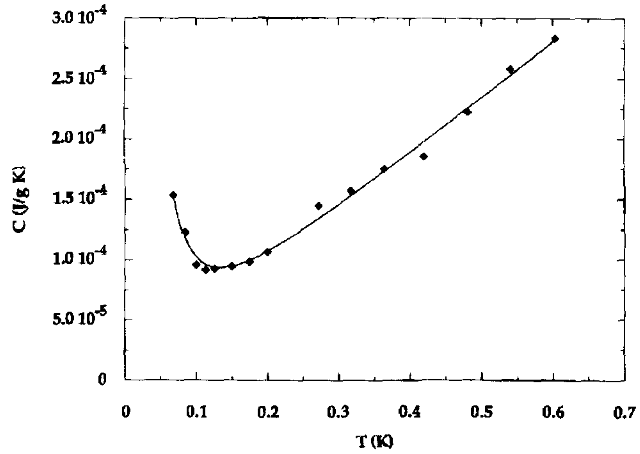

Figure 1 Measured heat capacity of 304 stainless steel and fit by the sum of a linear electronic term and a nuclear term

The decay fit a single time constant τ of the order of 10 s, which is much larger than any internal time constant. The heat capacity of the steel sample is then $C = G\tau$, since the heat capacity of the addenda was negligible. The data, as shown in *Figure 1*, are well fit by c_{ss} (T) = $(465T + 0.56T^{-2})$ μJ g^{-1} K^{-1}. The linear electronic term is in good agreement with previous experiments[5] at $T > 1$ K. The second term is a nuclear heat capacity typical in alloys containing transition elements with large nuclear spin such as manganese[6]. Type 304 ss nominally contains 1–2% Mn whose only isotope has $I = 5/2$.

We decreased the ADR time constant without significant increase in eddy current heating by gluing 25 μm thick longitudinal strips of copper to the outside of the ss container.

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