Kapton Capacitance Thermometry at Low Temperatures and in High Magnetic Fields

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Introduction

Reliable determination of the temperature for experiments at low temperatures and in high magnetic fields is an important issue and still a developing area. At ultra-low temperatures, the task of measuring temperature accurately, even in small magnetic fields, becomes increasingly difficult. The major cause of this difficulty is the long thermal relaxation time due to the poor thermal conductivity of materials and the thermal boundary resistance. In this report we outline a new type of capacitive temperature sensor, using commercial Kapton foil with very simple construction and small size.

Experimental

The thermometer consists of a capacitance using Kapton foil as the dielectric between two silver plates as shown in Figure 1. Wells were machined into the outer walls of the silver plates to accommodate silver powder that was sintered to the silver body to provide high surface area to liquid helium three that surrounded the cell. The entire thermometer was contained in a solid silver shell with a free interior volume around the thermometer to allow the helium three to circulate freely and maintain contact with the external bath. A silver tag forms part of the solid exterior and can be used to bolt to other systems whose temperature is to be measured, or the sample being measured can be connected to the same liquid helium three bath as the thermometer. The temperature dependence of the capacitor was calibrated with the ^{3}He melting point thermometer at zero magnetic field, and monitored with a vibrating wire viscometer at 14.8 T. The capacitance was measured using a low noise lock-in amplifier (NF model LI5640). The measurement was carried out using the High B/T Facility of the National High Magnetic Field Laboratory in Gainesville.

Results and Discussion

The performance of the capacitance thermometer was compared with the vibrating wire thermometer and a ^{3}He melting curve thermometer for $1.5 < T < 150$ mK, and for applied fields from 0 to 14.8 T. The results are shown in Figure 2.

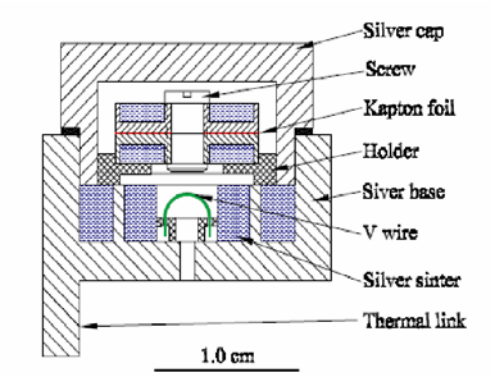

Figure 1. Schematic view of the capacitance thermometer.

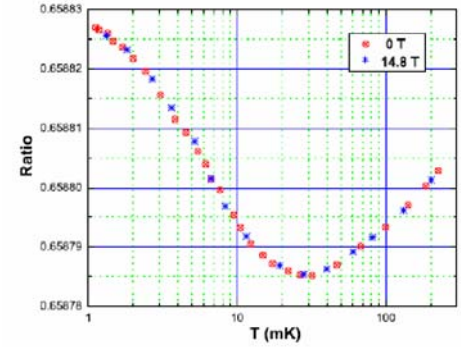

Figure 2. Performance of the capacitance thermometer.

Conclusions

The good sensitivity and the high independence of magnetic field variation indicate that the Kapton capacitance thermometer is a unique and valuable thermometer for applications at ultra-low temperatures in magnetic fields.