PRIMARY AND SECONDARY MILLIKELVIN THERMOMETRY IN MAGNETIC FIELDS

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Introduction

This instrumentation project has two primary goals: (1) production of thermometers with lower heat capacity and smoother field response than commonly used commercially available ruthenium oxide and ceramic metal oxide (CERMET) resistors and (2) development, characterization, and optimization of a comprehensive set of methods for cross-calibration of these and other resistive thermometers in fields up to at least 45 tesla at temperatures down to at least 50 mK.

Experimental

The thin film resistive sensors used in this work are miniature (0.25 mm x 0.25 mm x 10μm) gold-germanium thermometers [1] and nichrome heaters on oxidized Si substrates. The algorithms used to correct for magnetoresistance and to control temperature as the magnetic field is continuously swept have been presented elsewhere [2]. We have used a variety of methods to calibrate our sensors, including (1) cross calibration in field at regulated setpoints against a series of field-independent Coulomb blockade-based primary thermometers (CBT), (2) cross-calibration as a function of temperature in a series of fixed fields against 3He vapor pressure, (3) cross calibration as a function of field at fixed temperature using a capacitance transfer standard, a capacitance bridge and computer-based PID control and (4) cross calibration in zero field against commercially calibrated sensors.

Results and Discussion

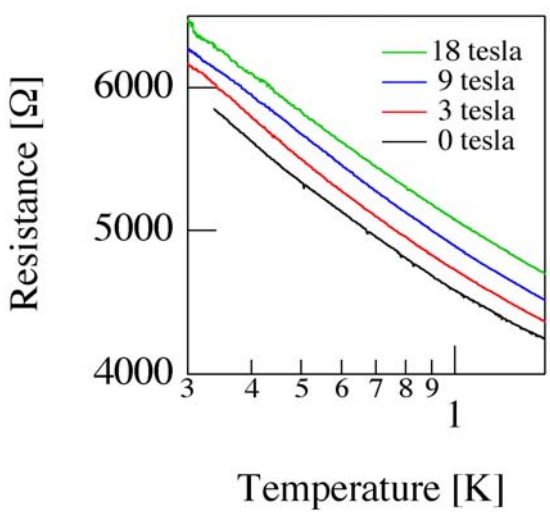

Figure 1: Magnetic field dependence of the resistivity of a sample Au_xGe_{1-x} thermometer (AuGe104132560).

To carry out method (1), we developed two methods of reliably measuring the differential conductance of these highly resistive tunneling devices: one using a specially constructed bridge circuit and a LakeShore 370 Resistance Bridge and the other using a Keithley Model 2182A nanovoltmeter and Model 6221 ac/dc current source [3].

Unfortunately, shifts in the room temperature resistance value of these sensors due to aging and/or electrostatic discharge lead to systematic errors in the calculated temperature. These sensors are no longer in production; we will re-evaluate the feasibility of using CBT devices once a new generation capable of use in zero field becomes available.

To carry out method (2), we constructed a special pressure-sensing insert for one of the top-loading probes for the new Janis 3He fridges. The 3He pressure can be continuously recorded as a function of field and temperature. This insert is now available for general use. Cross-calibration data for one of our AuGe sensors against 3He vapor pressure determined temperature (after head corrections) is shown in Fig. 1.

Methods (3) and (4) used standard instruments and practices.

Acknowledgements

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References

[1] Fortune, N.A., *et al.*, Review of Scientific Instruments, **69**, 133-138 (1998).
[2] Fortune, N.A., *et al.*, Review of Scientific Instruments, **71**, 3825-3830 (2000).