Magnetoresistance of Cernox™ and ROx™ Sensors in High Magnetic Fields

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Introduction

Experiments in magnetic fields must deal with the fact that all temperature sensors that hold a calibration are affected by the magnetic field. To get usable data, the error in the sensor must be removed by calibration of the field effect and calculation of the "true" temperature from the sensor signal and the strength of the magnetic field. This has led to a series of studies of various sensors over the years. The most recent have been of Cernox™ zirconium oxynitride sensors from Lake Shore Cryotronics. Published studies have been limited to fields under 35 teslas.[1,2] Data on one Cernox™ sensor to 60 T in a pulsed magnet[3] lead us to expect no surprises at higher fields at the temperatures measured but are not adequate for general use in correction schemes. There have been several studies of ruthenium bismuth oxide chips, including ROx™ sensors from Lake Shore Cryotronics and other sources but none published that relate directly to the present work. Our goals were to characterize the Cernox™ and ROx™ sensors mounted on Probe #4 of the System E ^{3}He refrigerator built by Janis Research for use in the 45 T hybrid magnet along with four additional Cernox™ sensors in order to suggest how randomly selected Cernox™ sensors might be corrected for field effects to 45 T.

Experimental

Measurements were done in the 45 T hybrid magnet of the DC High Magnetic Facility in Tallahassee. Probe #4 of the top loading cryogenic system was used for all measurements. We used the ^{3}He refrigerator for all the measurements, even those at temperatures above 4 K. Four Cernox™ sensors and one Lake Shore CS-501GR capacitance sensor were mounted on a sample holder machined from solid copper. The capacitance sensor was used in two ways: the first was in a control circuit to keep the temperature constant as the field varied; the second was as a temporarily calibrated, field independent, temperature sensor for measuring the true temperature in the presence of high magnetic field. We also recorded the resistances of the Cernox™ and ROx™ sensors built into Probe #4 and into the ^{3}He refrigerator. The capacitance sensor was calibrated against the Cernox™ sensor built into Probe #4 after it had equilibrated for an hour at a temperature close to the temperatures at which it was to be used for a day's magnet runs. It was calibrated again after the magnet time to measure its drift during the measurements. The "after" calibration could be used as the "before" calibration for the next day's experiments unless the probe was warmed to room temperature between runs.

Results and Discussion

Data showed good thermal contact between the Cernox™ sensors and the capacitance sensor. It was possible to control the temperature of the samples while sweeping the magnetic field as long as the temperature set point was less than about 4 K. Above that temperature, eddy current heating of the copper sample holder by the magnetic field ripple and sweep required that we hold the magnetic field fixed and sweep the temperature.

Conclusions

The following conclusions are tentative, pending completion of the data analysis. Capacitance sensors are useful at temperatures down to at least 400 mK and hold their temporary calibrations surprisingly well. Solid copper sample holders can be used in System E at temperatures below 4 K, but should not be used at higher temperatures. Individual Cernox™ and ROx™ sensors can be corrected for fields up to 45 T by comparison with a temporarily calibrated capacitance sensor.

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References

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