Dimensional Reduction in BaCuSi$_2$O$_6$

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INTRODUCTION

BaCuSi$_2$O$_6$ exhibits a crossover from a 3D Bose Einstein Condensate (BEC) critical exponent to a 2D critical exponent in the 0.65 K to 0.9 K temperature range, which early theories suggested is a result of perfect inter-layer magnetic frustration in the system [1]. BaCuSi$_2$O$_6$ is the only material to demonstrate this sort of behavior.

MAGNETOCALORIC EFFECT

We use the magnetocaloric effect (MCE) in Ba$_{0.9}$Sr$_0.1$CuSi$_2$O$_6$ as a tool to analyze its magnetic phase transitions, preparing the sample as follows:
1. Start with crystal of side lengths between 1 mm and 2 mm.
2. Sputter AuGe thin film onto its surface. Then sputter gold pads on for contacting leads.
3. Drill out a dimple in a piece of G-10, just large enough for the sample to rest in. Then secure the sample in this dimple by stretching dental floss across, minimizing thermal contact between the sample and the rest of the probe in the magnet. Finally, mount two twisted pairs of constantan wire to the gold pads with silver paint, allowing for four-terminal measurement of the resistance across the AuGe thin film. Once properly wired and calibrated, this thin film functions as a resistance thermometer because of its well-defined relationship between temperature, magnetic field, and resistance [5].

RESULTS

Below is the MCE data collected and processed at the National High Magnetic Field Laboratory’s Pulsed Field Facility at Los Alamos National Lab (LANL), combined with data collected and processed at the Institute for Solid State Physics (ISSP) at the University of Tokyo using an adiabatic approach. The LANL experiments mostly ran at lower temperatures than ISSP to gain a more complete understanding of the properties of Ba$_{0.9}$Sr$_0.1$CuSi$_2$O$_6$ in a wider range of conditions.

DISCUSSION

The MCE data confirm the existence of field-induced magnetic order between 22.5T and 46.5T as observed in the pure material with slightly reduced critical fields. The analysis of the phase boundary in combination with recent torque data obtained down to 0.3K suggest that no dimensional reduction from 3D to 2D is observed in the critical exponent. Further investigations of the MCE need to be conducted to:
- Repeat the same experiment while maintaining truly adiabatic conditions in the sample space (the small "loops" that appear in the graph for each temperature suggest resistance heating of the sample between the upsweps and downsweps of the magnet).
- Revisit the crystal’s behavior in lower fields to determine if any of the anomalies in the LANL data below 20 T are substantial.
- Analyze potential Bose glass behavior in Ba$_{0.9}$Sr$_0.1$CuSi$_2$O$_6$.

REFERENCES


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