Investigating the Magnetic Structures of Pure and Doped $SrCu_2(BO_3)_2$ Under Pressure

S. Haravifard (U. Chicago/ANL); D. Graf, S. Tozer (NHMFL); J. Lang, G. Srajer (ANL); B. Gaulin (McMaster U.); D. Silevitch, T. Rosenbaum (U. Chicago)

Introduction

$SrCu_2(BO_3)_2$ or SCBO for short, is one of the few real-world materials that corresponds to the Shastry-Sutherland two-dimensional, quantum spin model. The exchange couplings for SBCO lie just below the critical value placing it in the gapped non-magnetic singlet ground state; thus only a slight change in exchange couplings drives the system across quantum phase transitions. This slight change suggests the application of chemical doping and pressure as tuning parameters. [1, 2]

Recently, interest has focused on a finite magnetization of SCBO at low temperatures, which develops at sufficiently high magnetic fields, wherein the lowest energy of the three triplet states is driven to zero energy. This is related to Bose-Einstein condensation of the triplet excitations, which in pure SCBO occurs for fields near 20 T and higher. At higher magnetic fields, plateaus have been observed in the magnetization, which have been interpreted in terms of preferred filling of the singlet ground state with increasing densities of triplet excitations. [3]

While pure SCBO has been well studied, there is little information on this quantum magnet in the presence of dopants. This problem is very interesting by analogy with the remarkable properties of dopant quasi two-dimensional Mott insulators and high-temperature superconductivity. SCBO is itself a Mott insulator, and the theory of doped Mott insulators on the Shastry-Sutherland lattice shows the possibility of several different superconducting phases as a function of doping. [4]

Experimental

We have conducted high magnetic field measurements on pure and Mg doped SCBO samples at ambient pressure using the tunnel diode oscillator (TDO) technique. The data was collected at the NHMFL (FSU) using a 35T resistive magnet and a He3 cryostat. Additionally, high magnetic field measurements were conducted under pressure in a clamp-type cell using the TDO technique. This data was collected at the NHMFL (FSU) using an 18T superconducting magnet and a dilution refrigerator.

Results and Discussion

High magnetic field measurements performed on pure SCBO using TDO in static magnetic fields up to 35 T revealed the onset of the 1/8 magnetic plateau at H~28 T and T~350 mK, while in the doped system the first plateau appeared at slightly lower magnetic fields. Additionally in the doped system some structures in the frequency signal were observed at fields below the 1/8 plateau, which we associate with the "in-gap" states.

Furthermore the results showed that as the pressure was increased, the field at which the magnetic plateaus appeared decreased.

Conclusions

Although this is an ongoing study and future experiments are needed to fully resolve the phase diagram, so far results of the measurements are very promising. They indicate that the combination of new in-gap states introduced into the system due to chemical doping and the application of pressure will drive the system across a phase transition, which can then be manipulated by applied magnetic field. The nature of the ground states and their relation to theory need to be clarified.

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