High Pressure Measurements of Quantized Magnetization Plateaus in Pure and Doped Shastry-Sutherland Materials

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Introduction

$SrCu_2(BO_3)_2$ (SCBO) is one of the few real-world materials that correspond to the Shastry-Sutherland 2-dimensional model, with corner-sharing Cu^{2+} S=1/2 dimers lying on a square lattice and only weak interactions between adjacent planes. The exchange couplings for SBCO lie just below the x=J'/J=0.69 critical value placing it in the gapped non-magnetic singlet ground state; thus only a slight change in x drives the system across the quantum phase transition. This slight change suggests the application of chemical doping and pressure as tuning parameters. [1, 2]

While pure SCBO has been well studied, there is little information on this quantum magnet in the presence of dopants. SCBO is a Mott insulator, and the theory of doped Mott insulators on the Shastry-Sutherland lattice shows the possibility of several different exotic phases as a function of doping. [3]

Additionally, interest has focused on 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 (BEC) 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. [4]

Experimental

We have conducted high magnetic field measurements on single crystal samples of pure and Mg doped SCBO as function of pressure using tunnel diode oscillator (TDO) technique. Additionally, high magnetic field measurements were conducted under pressure (up to ~2.5 GPa) in a clamp-type cell using the TDO technique. The data was collected using 35T resistive magnet in a ^{3}He cryostat.

Results and Discussion

High magnetic field measurements performed on pure SCBO revealed the onset of the 1/8 magnetic plateau at H~28 T and T~350 mK, while in the Mg doped system the first plateau appeared at slightly lower magnetic field. 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 and subsequently the gap energy was decreased, the magnetic field at which the magnetic plateaus appeared decreased systematically. The line shape of the data showed apparent differences at pressures below and above ~ 2 GPa which is an indication of previously observed quantum phase transition.

Conclusions

We have used pressure as tuning parameter to drive the system across the quantum phase diagram and studied the evolution of the quantized magnetic plateaus. Additionally the collected data indicate that the combination of new in-gap states introduced in the system due to chemical doping and the application of pressure will result in systematic change in the line-shape of the magnetic plateaus and the field at which they appear.

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References

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