Magnetization and ESR studies of $Cd(Cu_{1-x}Zn_x)_2(BO_3)_2$

We have investigated the magnetic properties of $Cd(Cu_{1-x}Zn_x)_2(BO_3)_2$ (x=0, 0.1 and 0.2) using high field magnetization and high frequency ESR in IMR. The Zn-substitution and field dependence of the magnetization and antiferromagnetic resonance modes suggest a competition between intradimer and inter-tetramer couplings.

$CdCu_2(BO_3)_2$ has attracted research interest as a counterpart of the well-investigated Shastry-Sutherland compound $SrCu_2(BO_3)_2$ [1]. In contrast to $SrCu_2(BO_3)_2$, $CdCu_2(BO_3)_2$ has a long-range magnetic ordering at T_N=9.8 K [2]. It is related to the fact that the substitution of Sr^{2+} by Cd^{2+} induces a structural transformation while changing a magnetic structure to a spin tetramer. $Cu(1)O_4$ plaquettes form structural $Cu(1)_2O_6$ dimers while tetrahedrally distorted $Cu(2)O_4$ plaquettes share a common O atom with the dimers, forming a spin tetramer. The tetramer consists of strong intradimer coupling and weak intra- and inter-tetramer couplings. Thus, this compound offers a test bed to study a competition between a singlet state and a long-range ordered one in a single sample.

Fig.1 shows the high-field magnetization curve of $Cd(Cu_{1-x}Zn_x)_2(BO_3)_2$ (x=0, 0.1 and 0.2) measured at T=1.5 K. The magnetization of x=0 increases quasi-linearly with increasing field and exhibits a half-step magnetization plateau at $H_{1/2}$=22.4 T and a spin-flop transition at H_{SF}=1.69 T. In the 1/2-plateau phase, the spin dimer recovers a spin singlet state while other two tetramer spins are polarized parallel to the external field.

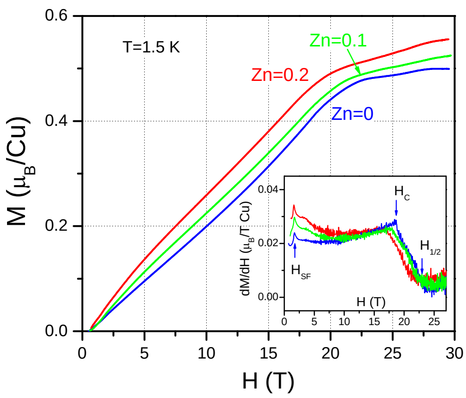

Fig. 1 Magnetization curve of $Cd(Cu_{1-x}Zn_x)_2(BO_3)_2$.

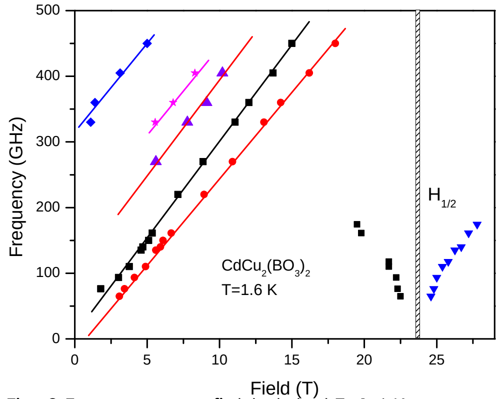

Fig. 2 Frequency vs. field plot at T=1.6 K

With increasing Zn content to x=0.2, both H_{SF} and $H_{1/2}$ are reduced by 15% and the magnitude of the magnetization is systematically enhanced. This is due to a weakening of inter-tetramer coupling and a creation of free spins by dilution effects.

Fig. 2 shows the frequency-field plot at T=1.6 K. We observe five modes which are assigned to the antiferromagnetic resonance modes pertaining to a four sublattice of the spin tetramer. In addition, one low-lying mode appears in the vicinity of the critical field $H_{1/2}$. This is ascribed to the magnetic field induced polarized phase.

In summary, the Zn-substitution and field dependence of magnetic behaviors rely on the peculiar spin arrangement comprising the strongly coupled Cu(1) dimer spins and the weakly coupled Cu(2) tetramer spins. The half-step magnetization and its Zn dependence is largely determined by the polarization and dilution effects of the Cu(2) spins, respectively.

References

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