Magnetic Field-Induced Transient Steps In The Magnetic, Ferroelectric, And Structural Properties Of A Frustrated Spin Chain Multiferroic $Ca_3(Co,Mn)O_6$

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Introduction

Transient step behaviors were observed in frustrated spin chain multiferroic system $Ca_3(Co,Mn)O_6$ (CCMO) These steps are observed in magnetization, magnetostriction, and magnetically-induced electric polarization only within a range of very fast magnetic field sweep rates. While this behavior resembles that of an isostructural compound $Ca_3Co_2O_6$, which has recently been described as a realization of the ANNNI model, CCMO possesses more complex magnetic interactions due to the Mn^{4+} ions and forms an antiferromagnetic/multiferroic ground state.

Experimental

Single-crystalline samples were grown by the flux method [1]. Magnetization in pulsed magnets was measured using a extraction magnetometer. Two magnets were used to generate different sweep rates: a generator-driven 60 T shaped-pulse magnet and a capacitor-driven 65 T pulse magnet. Magnetostriction was measured using an optical fiber grating method [2]. Electric polarization was obtained by integrating the magneto-electric current using a current amplifier.

Results

Figure 1(a) short-pulse magnetization (up to 9 T) data CCMO measured along the *c*-axis. Two step features are observed that are not found in the DC field measurement. This is shown more clearly in the dM/dH versus H curves (Fig. 1(b)). Two strong peaks are found in the dM/dH curves, although detailed structure differs by Co/Mn ratio. The step features are also observed in magnetostriction (Fig. 1(c)) and electric polarization (Fig. 1(d)).

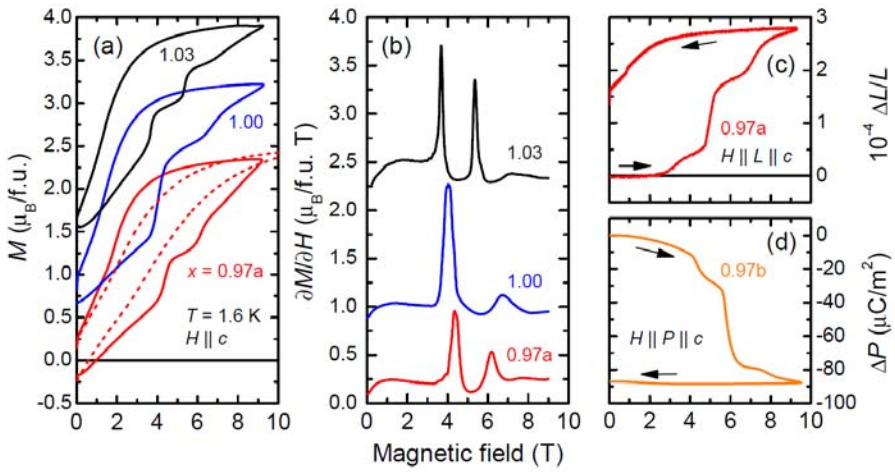

Figure 1. (a) Magnetization versus magnetic field measured using pulse magnetic fields (solid lines) with different ratio between Co and Mn. DC manetic field data is shown in dotted line. (b) First derivative of magnetization versus magnetic field. (c) Magnetostriction as a function of magnetic field. (d) Electric polarization as a function of magnetic field.

Conclusions

There is a certain threshold to observe the transient features in CCMO (not shown). The existence of sweet spot in transient behavior can be explained by the 'avalanche' scenario. When magnetic field is applied magnetic domains form in 'avalanches'. At certain driving-rate these small avalanches can be merged together and show larger jumps. This behavior hinges on the frustrated nature of this system which forms a 2D triangular lattice with multiple exchange paths between Co and Mn spins.

Acknowledgements

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References

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[2] R. Daou et al., Rev. Sci. Instrum. 81, 033909 (2010).