Transient Magnetic States in Ca_3CoMnO_6 Compound

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Introduction

Frustration plays an important role in many magnetic systems. Competing magnetic exchange interactions prohibit the system from having simple magnetic order and give rise to either a modulated structure with long wavelength or even no long range order at all. This often produces many metastable states that fail to establish equilibrium in reasonable time scales with the environment. Ca_3CoMnO_6 is one of the systems that show such time dependent phenomena [1]. We show that such effect can have much shorter time scale using very fast magnetic field sweep rates.

Experimental

Magnetization in pulse magnets is measured using an extraction magnetometer. For DC measurements, we used the vibrating sample magnetometer option in PPMS. Magnetostriction is measured using a fiber grating method [2]. Electric polarization is integrated from the change of charge (i.e. current) using a current amplifier. Two types of magnets were used to vary the ramp rate dependence. Capacitor bank driven short pulse magnet (pulse width ~50 ms) was used to achieve ramp rate ranging from ~1000 T/s to 6000 T/s. Generator driven long pulse magnet was used to achieve ramp rate from 10 T/s to 150 T/s.

Results and Discussion

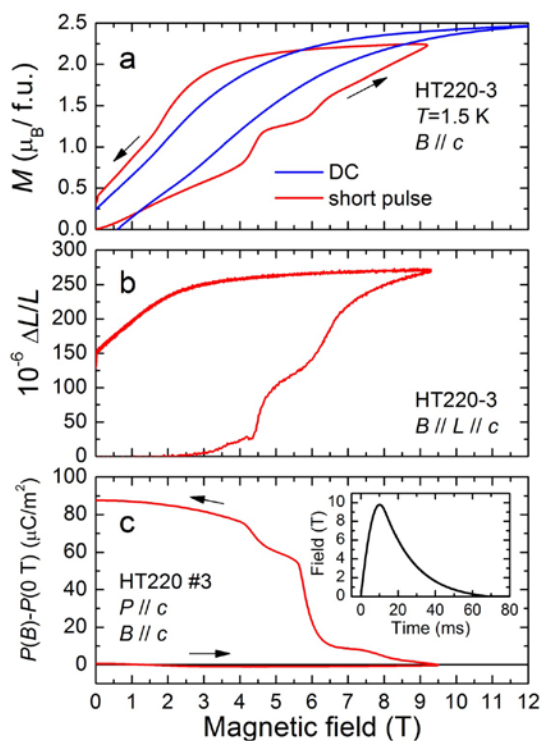

Figure 1. Magnetization (a), magnetostriction (b), and electric polarization (c) as a function of magnetic field. Inset in 1c shows the magnetic field profile of the pulse magnet.

Figure 1a shows the pulse magnetic field measurement data up to 10 T. While, the magnetization curve has a smooth curve for both up and down sweeps in static measurements. A striking difference is observed in pulse magnetic field run. One can find two clear steps during the up sweep and a slope change near zero field at the down sweep. This transient phase transition is also observed in other measurements such as magnetostriction (**Figure 1b**) and electric polarization (**Figure 1c**) using the same magnet. The maximum length change induced by field is $\Delta L/L$~300 X 10^{-6}.

This material is also known to show ferroelectric behavior with magnetic order [3]. Following the magnetization and magnetostriction results, electric polarization also shows transient phase transitions in fast pulse magnetic field. The change of electric polarization is noticeably large at the 6 T step compared to the 4 T one while the amplitude of the two steps in magnetization and magnetostrictions are similar.

Conclusions

The transient nature of Ca_3CoMnO_6 comes from the frustrated nature of spins in an Ising-chain magnet. The sudden jumps are due to the Ising-like nature of Co spins while the Mn spins reorient at higher magnetic fields. We expect a strong competition in both inter- and intra-chain exchange interactions.

Acknowledgements

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References

[1] S. Agrestini *et al.*, Phys. Rev. Lett. 106, 197204 (2011).
[2] R. Daou *et al.*, Rev. Sci. Instrum. 81, 033909 (2010).
[3] Y. Choi *et al.*, Phys. Rev. Lett. 100, 047601 (2008); Y. Jo *et al.*, Phys. Rev. B (2009).