# Experimental Report



**Proposal:** **5-31-2276** **Council:** 10/2012

**Title:** A variable temperature and field neutron study of the novel MR material Zn0.7Cu0.3Fe2O4

**This proposal is a new proposal**

**Researh Area:** Chemistry

**Main proposer:** **MCLAUGHLIN Abbie**

**Experimental Team:** MCLAUGHLIN Abbie

**Local Contact:** BRUNELLI Michela

**Samples:** Zn0.7Cu0.3Fe2O4

| Instrument | Req. Days | All. Days | From | To |
|---|---|---|---|---|
| D20 | 2 | 1 | 16/05/2013 | 17/05/2013 |

**Abstract:**

We have investigated the magnetic and magnetoresistant properties of the spinels Zn1-xCuxFe2O4. Negative magnetoresistance (MR) was observed for the whole series at 290 K and results show that as x increases from 0 – 0.3 the magnitude of the –MR recorded in a 9 T field increases from -2% to -9.8%. ZnFe2O4 is antiferromagnetic (TN = 10 K) but upon increasing x a ferrimagnetic or canted antiferromagnetic transition is observed and Tc increases with increasing x. Zn0.7Cu0.3Fe2O4 exhibits a broad magnetic transition at around 350 K. A second transition is also observed at 20 K. We propose that the sizeable –MR observed at room temperature in Zn0.7Cu0.3Fe2O4 arises due to a change in magnetic structure from a non-collinear Yafet-Kittel magnetic ordering to a collinear ferimagnetic structure upon applying a magnetic field. In order to investigate the magnetoresistant and magnetic properties further we propose to perform variable temperature and field neutron diffraction studies on the material Zn0.7Cu0.3Fe2O4, which exhibits the largest –MR.

Experiment 5-31-2276, D20

# A variable temperature and field neutron study of the novel MR material $Zn_{0.7}Cu_{0.3}Fe_2O_4$

## Introduction

A negative magnetoresistant material exhibits a large reduction in electronic resistivity upon application of a magnetic field. Magnetoresistance is the change of electrical resistivity, ρ, in an applied magnetic field H, defined as MR= (ρ(H)-ρ(0))/ρ(0))). Such materials are of technological importance and are applied in magnetoresistive sensors and spintronic devices in which electron spins are used to process information. Because of the large negative magnetoresistances observed in thiospinels such as $FeCr_2S_4$ [1] ($MR_{6T}$ (170 K) = -20 %) we have investigated the MR properties of the oxide spinels $Zn_{1-x}Cu_xFe_2O_4$. Some of these materials have magnetic transition temperatures above room temperature which could therefore result in significant room temperature MR. The series $Zn_{1-x}Cu_xFe_2O_4$ (x = 0, 0.1, 0.2, 0.3, 0.4 and 0.5) was synthesized). Negative magnetoresistance was observed for the whole series at 290 K and results show that as x increases from 0 – 0.3 the magnitude of the –MR recorded in a 9 T field increases from -2% to -9.8% (Figure 1), but decreases with further doping. Variable temperature MR studies show that upon cooling the magnitude of –MR increases further so that $MR_{7T}$ (200 K) = -21 % (Fig. 1). The $Zn_{1-x}Cu_xFe_2O_4$ materials are all semiconducting. $ZnFe_2O_4$ is antiferromagnetic ($T_N$ = 10 K) [2] but upon increasing x a ferrimagnetic or canted antiferromagnetic transition is observed and $T_c$ increases with increasing x. $Zn_{0.7}Cu_{0.3}Fe_2O_4$ exhibits a broad magnetic transition at around 350 K in the magnetic susceptibility.

## Results

In order to investigate the magnetic behaviour of $Zn_{0.7}Cu_{0.3}Fe_2O_4$, variable temperature neutron diffraction data were recorded between 380 K and 5 K on D20 with increments of 5 K. Below the magnetic transition of 350 K, there is no evidence of magnetic Bragg peaks or additional intensity on top of the structural peaks and hence no evidence of long range magnetic order. However below the magnetic transition temperature a huge diffuse scattering signal appears broadening the (111) diffraction peak.

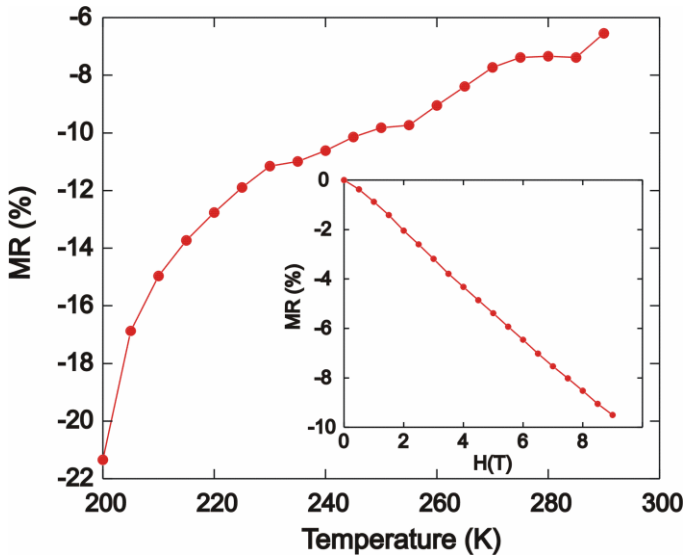


Figure 1: Variation of the magnetoresistance (MR) of $Zn_{0.7}Cu_{0.3}Fe_2O_4$ with temperature, recorded in a 7 T field. The inset shows the field variation of the MR at 290 K.

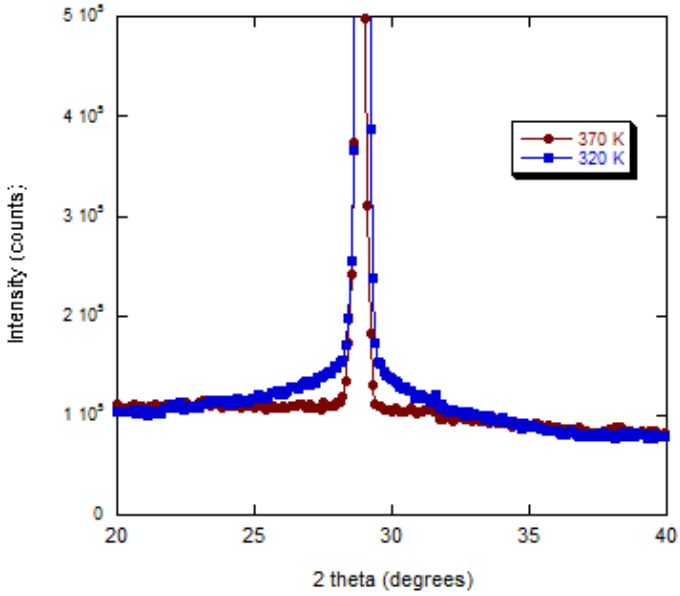


Figure 2: Observation of diffuse scattering observed below 350 K, broadening the (111) diffraction peak.

The considerable broadening of the 111 peak below 350 K suggests the presence of magnetic spin clusters. Magnetic spin clusters rather than long range ferromagnetic behaviour is most likely observed due to the high concentration of diamagnetic $Zn^{2+}$ within the sample, inhibiting exchange between Fe and Cu. The large MR in this system therefore most likely arises as a result of a reduction in spin scattering when the magnetic clusters align with the magnetic field.

References

1. A. P. Ramirez, R. J. Cava and J. Krajewski, *Nature* **386**, 156-159 (1997).
2. W. Schiessl *et al*, Phys. Rev. B: Condens. Matter. **53**, 9143–9152 (1996).