Experimental report

13/06/2020

Proposal: **5-31-2631** **Council:** 10/2018

Title: TUNING MAGNETIC ANISOTROPY AND SPIN-ORBIT COUPLING IN YBa(Cu1-xCox)FeO5 HIGH-TC SPIRAL MULTIFERROIC

Research area: Materials

This proposal is a new proposal

Main proposer: **Jose Luis GARCIA MUNOZ**

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Local contacts: Oscar Ramon FABELO ROSA

Samples: YBa(Cu1-xCox)FeO5 x=0; 0.02; 0.05; 0.10; 0.15;0.25; 0.50 (Ar, Air)

Instrument	Requested days	Allocated days	From	To
D1B	0	3	28/06/2019	01/07/2019
D20	3	0		

Abstract:

The low-magnetic ordering temperatures (typically <100 K) critically restrict the potential uses of magnetoelectric multiferroics for spintronics and low-power magnetoelectric devices. The origin of the multiferroic magnetic spirals in YBaCuFeO5 (a lattice without geometric frustration) is subject of debate. To give account of the anomalously high critical temperature for magnetic-spiral order new theoretical models based on the presence of chemical disorder and Random Magnetic Exchanges are being considered. As an strategy to tune the magnetic anisotropy and spin-orbit coupling in the system, we investigate the multiferroic properties of the isovalent substitution of Cu2+ by Co2+ in YBa(Cu1-xCox)FeO5.

28^{th} – 30^{th} June 2019

Experimental title:

Tuning magnetic anisotropy and spin-orbit coupling in $YBa(Cu_{1-x}Co_x)FeO_5$ high-Tc spiral multiferroic

Participants: Arnau Romaguera, Xiaodong Zhang, Jose Luis Garcia-Munoz, Oscar Fabelo

Abstract

The low-magnetic ordering temperatures (typically <100 K) critically restrict the potential uses of magnetoelectric multiferroics for spintronics and low-power magnetoelectric devices. The origin of the multiferroic magnetic spirals in $YBaCuFeO_5$ (a lattice without geometric frustration) is subject of debate. To give account of the anomalously high critical temperature for magnetic-spiral order new theoretical models based on the presence of chemical disorder and Random Magnetic Exchanges are being considered. As an strategy to tune the magnetic anisotropy and spin-orbit coupling in the system, we investigate the multiferroic properties of the isovalent substitution of Cu^{2+} by Co^{2+} in $YBa(Cu_{1-x}Co_x)FeO_5$.

Experimental report

There were no problems with the beam, cryofurnace, diffractometer during the measurements, and neutron patterns could be collected with the desired temperature range, between 10 and 500K.

In this experiment we measured 7 samples of $YBaCu_{1-x}Co_xFeO_5$ with x= 3%, 5%, 7.5%, 10%, 12.5%, 15% and 20%. All samples have been prepared using conventional solid-state reaction method. The same cooling procedure was applied for all the compositions (300º/h cooling). Most of the samples were measured in dynamic mode by means of temperature ramps. Selected heating rates were between 1.4 and 3K/min, along the temperature range 10-500K and using a wavelength λ=2.52Å. Additional measurements were performed at several fixed selected temperatures with longer counting times. In most of the samples patterns were collected at T=10K, 300K and 500K with the same wavelength. The last temperature T=500K corresponds to the paramagnetic state.

First of all, phase transition involving the appearance of new magnetic Bragg reflections are clearly observable at T_{N1}, $T_{N1'}$ and T_{N2} as shown in Fig. 2. A strong tuning of the transition temperatures T_{N1}, $T_{N1'}$ and T_{N2} was observed by introducing Co in this structure. The strong impact in the successive magnetic transition temperatures for each composition is shown in Fig. 1 (the sample x=0% was measured before this time). From these results, T_{N1} decreases with increasing Co content, whereas $T_{N1'}$ shows an opposite evolution as Co content increases. It is enhanced around 125 K for x=0.2.

In these measurements we have detected four different phases in $YBaCu_{1-x}Co_xFeO_5$ with x= 3%, 5% and 10% within the temperature range of our measurements (10-500K): (i) the commensurate (CM) AF1 collinear phase which is characterized by the magnetic propagation vector k = (1/2 1/2 1/2); (ii) the incommensurate (ICM) phase which is characterized by the magnetic propagation vector k = (1/2 1/2 1/2±q); (iii) the commensurate (CM) AF1' collinear phase which is characterized by the magnetic propagation vector k = (1/2 1/2 0); (iv) the paramagnetic phase; three phases were detected in x=7.5%, 12.5% and 15%, those referred above in (i), (iii) and (iv). In the composition with the highest doping (x=20%), only one ordered magnetic phase occurs, identified as the commensurate (CM) AF1' collinear phase, in which magnetic sublattices are coupled antiferromagnetically within the ab plane, according to the magnetic propagation vector k = (1/2 1/2 0).

By means of Rietveld refinements, the temperature evolution of the neutron patterns for each composition has been fully analyzed and the evolution of the main magnetic parameters has been extracted, including the amplitude of the ordered moments and the relevant inclination angles which give account of the evolution of the easy-axis by doping and inform upon the relevance of the modifications in the magnetic anisotropy in the structure by Co doping. Main structural information has been also extracted (e.g. Fig. 3), mainly from the neutron patterns collected in paramagnetic state at 500K. These neutron results are being combined with macroscopic measurements and information obtained from spectroscopic XAS measurements performed at the ALBA synchrotron and will be conveniently published.

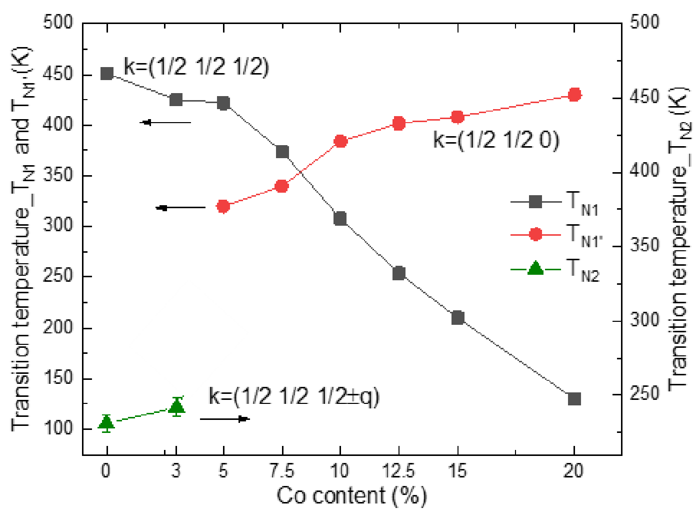

Fig. 1. The ordering temperatures T_{N1}, $T_{N1'}$ and T_{N2} as a function of Co content.

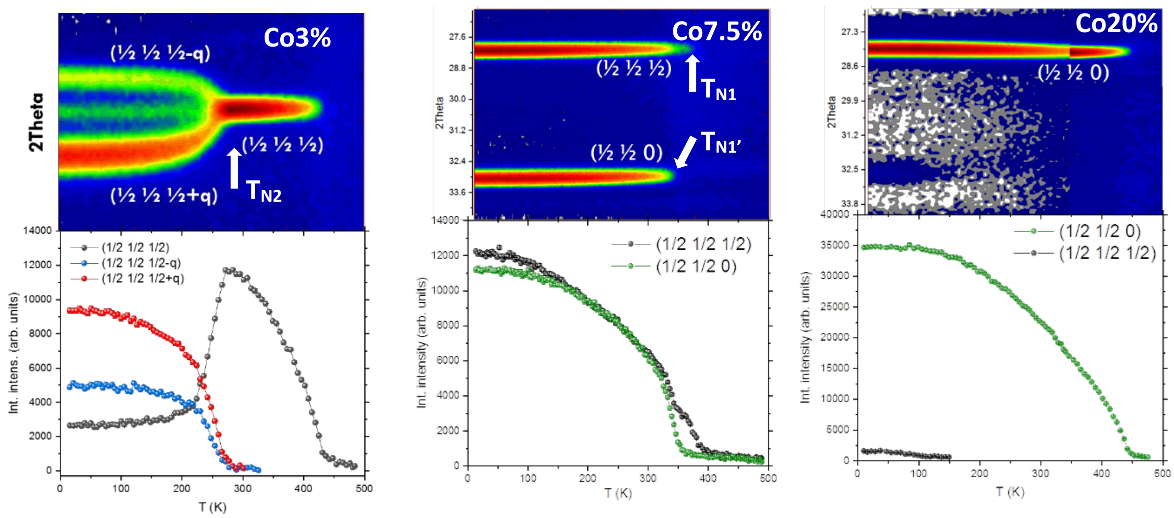

Fig. 2. Contour map and evolution of selected integrated intensities showing the temperature dependence of magnetic Bragg reflections for $YBaCu_{1-x}Co_xFeO_5$ with x=3%, 7.5% and 20%.

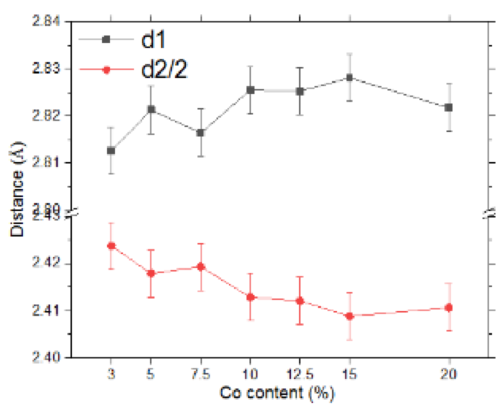

Fig. 3. Evolution of the bilayer thickness (d2) and the separation between bilayers (d1) with Co content.