ESRF	**Experiment title:** Anomalous magnetic behaviour in FeCuZr ball-milling alloy	**Experiment number**: HD-375
Beamline: BM29	**Date of experiment**: from: May 16th, 2009 to: May 19th, 2009	**Date of report**: July 13th, 2009
Shifts: 9	**Local contact(s)**: Dr. Carmelo Prestipino	*Received at ESRF:*

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In the proposal of experiment HD-375 we proposed to perform EXAFS at several temperatures between 5K and 600K with nomimal composition $(Fe_{0.5}Cu_{0.5})_{100-x}Zr_x$ with x = 0, 9, 13, 17, 30, 40 at%, obtained by High Energy Ball Milling (HEBM), to investigate the thermal expansion in samples. According to x-ray diffraction, samples are amorphous or nanocrystalline with an fcc structure, depending on the Zr content. We have previously studied the thermal expansion in samples with x = 13 at.% and x = 17at.% [i]

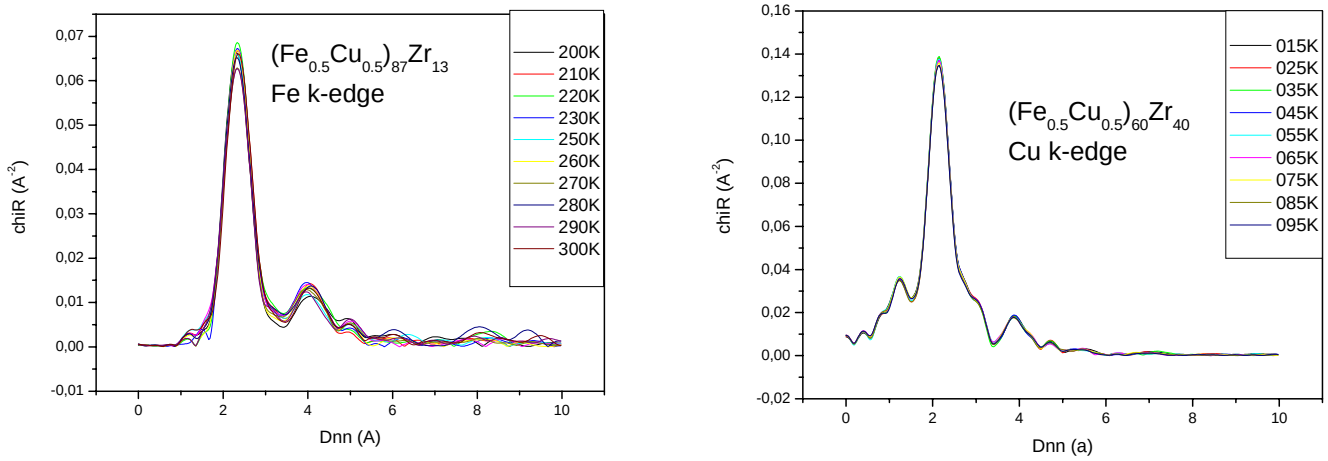
The experimental observation shows that fcc-$Fe_{50}Cu_{50}$ is ferromagnetic with Curie Temperature (TC) above 550K. This behavior has attracted interest since fcc-Fe and fcc-Cu are both non-magnetic in their ground state. Some authors have attributed such behaviour to magnetovolume effects, since the fcc lattice is expanded with respect to that of Cu. We have also been able to obtain amorphous FeCu rich alloys by adding Zr at $Fe_{0.5}Cu_{0.5}$ composition. Metastable alloys of nominal composition $(Fe_{0.5}Cu_{0.5})_{100-x}Zr_x$ (x = 0-40 at. %) have been synthesized by HEBM. The alloy formation has been confirmed by XRD and Mössbauer spectroscopy. The samples are in powder form. Depending on Zr content, samples are nanocrystalline with fcc structure (x<13 at.%) or amorphous for higher Zr content. We have also observed that TC in these samples decrease with at.% Zr between near Room Temperature in sample x = 17at.% and below 50K in sample with x = 40 at.%. For these alloys it has been observed that:

- Thermo-remanence (TRM) exhibits an anomalous increase above TC. TRM measurements are performed by cooling the sample under the presence of an applied magnetic field down to 5K. Then, the field is removed and the remanence is measured while heating up the sample. TRM decreases with increasing temperature until it reaches a minimum value for temperatures close to the Tc. Further increase in temperature promotes a spontaneous increase of the magnetization that is observed up to 300K. This increase of the spontaneous magnetization in absence of an applied field could be related with anomalous changes in the interatomic distances with temperature, as occurs in invar alloys.
- An anomalous increase of the coercive field H_c above RT is present. In all cases, an anomalous magnetic hardening of the material is observed for temperature above TC

In order to explain the phenomena, preliminary EXAFS measurements have been performed at several temperatures, at the iron K-edge, in Spline-BM25 at ESRF in samples with x = 13, 17 at.%. These experiments indicate that the thermal expansion is accompanied by an increase of the magnetic signal on the thermo-remanence measurements. The increase of first near-neighbour's distances with temperature

produced by thermal expansion can yield to an enhancement of the density of the states at Fermi level that could promote the appearance of a new magnetic order above TC [i], [ii].

This way, in HD-375 we have performed EXAFS spectra in samples with x = 13at.% between 200K to 300K and x = 40at.% between 5K and 105K. When EXAFS spectra have been obtained, we perform Fourier Transfom (FT) to know near-neighbour's distance and we study the evolution near-neighbour's distance with the temperature around TC of each sample. Fig 1 shows the FT obtained from EXAFS spectra performed in x = 13 at.%Zr and x = 40 at.%Zr samples around TC on Fe k-edge. Fig 2 shows the FT obteined from EXFAS performed in x = 40 at.%Zr sample on k-edge.



$(Fe_{0.5}Cu_{0.5})_{87}Zr_{13}$ Fe K- edge

$(Fe_{0.5}Cu_{0.5})_{60}Zr_{40}$ Fe K- edge

Fig 1. FT of EXAFS spectra taken at the Fe K - edge on x = 13, 40 at.% samples around TC

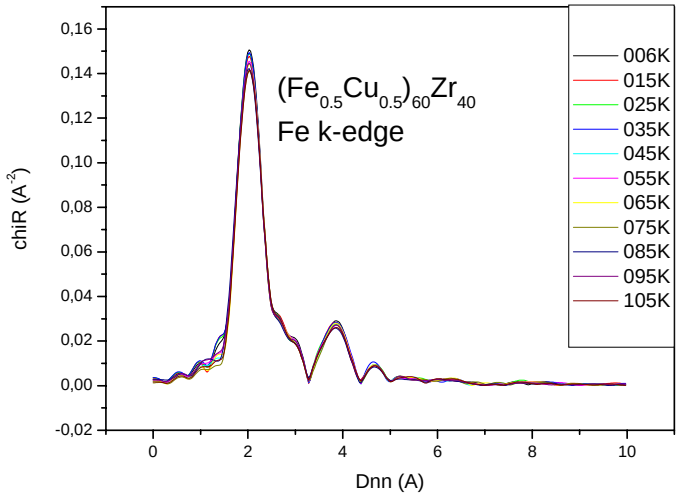


Fig 2. FT of EXAFS spectra taken at the Cu K- edge on the sample $(Fe_{0.5}Cu_{0.5})_{60}Zr_{40}$ around TC (TC = 45K)

Structural and near-neighbour's distance analysis extracted from EXAFS signal are better studied by their Fourier Transform. It can be seen from figures 1 and 2 that preliminary EXAFS analysis show changes in iron and copper local environment with temperature. This could be explained with the thermal expansion in these samples.

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i A. Martinez *et al.*, IEEE Transactions on Magnetics, Volume 44, Issue 11, Nov. 2008 Page(s):3887 - 3890

ii A. Hernando *et al. Phys Rev B* 61 (5), 3219 (2000)