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$k(\text{Å}^{-1})$

Report:

We studied the local atomic structure of [Ni/Cu]xN magnetic multilayers by means of EXAFS at the Ni K-edge. They are considered as a model system in magnetism since they show a clear relationship between magnetic and structural properties. Spintronic devices are built by functional blocks made by repetitions of a bilayer structure resulting in a kind of synthetic magnetic material [1]. In a recent work, subject of a PhD thesis [2], we have shown that important magnetic parameters as the coercive field, H_c and the domain size, D, can be controlled in these functional blocks. In particular, the effective anisotropy constant shows strong differences between t_{Ni}= 3 nm and t_{Ni}= 4 nm blocks as a function of the blocks repetition number, N.

We performed EXAFS experiments at the Ni K-edge at beamline BM30B on a series of samples with t_{Ni}= 3 nm and t_{Ni}= 4 and N varying from 1 to 5. The samples were grown by Molecular beam Epitaxy in our group of INA at the Zaragoza University. The measurements were performed in fluorescence mode with a beam incidence angle equal to 5º and 85º corresponding to a beam polarization vector nearly parallel ($\boldsymbol{\varepsilon_{par}}$) and perpendicular ($\boldsymbol{\varepsilon_{per}}$) to the sample surface respectively (growth direction (001)) to exploit the strong anisotropy of the EXAFS probe at the K-edge. In this way, considering the Ni fcc crystalline structure, we probe separetely the $a_{//}$ and $a_{\perp}$ parameters that correspond to the II coordination shell of the central Ni atom ($d_{II\text{-}in}$, $d_{II\text{-}out}$) and we can obtain the in-plane and out-of-plane strain values $\varepsilon_{//}$ and $\varepsilon_{\perp}$. For pseudomorphic Ni on Cu, $\varepsilon_{\perp} = -2(C_{12}/C_{11})\,\varepsilon_{//}$=-0.03 being the misfit strain Ni/Cu η = -0.025 (a_{Cu} = 3.61 Å and a_{Ni} = 3.52 Å).

For the EXAFS data analysis theoretical amplitudes and phase shifts were calculated *ab-initio* by FEFF8 code taking into account the beam polarization. Scattering potentials were calculated in the muffin-tin approximation in a self-consistent way, with a Hedin-Lundqvist approximation for exchange and inelastic losses. Background subtraction in the EXAFS region was performed by AUTOBK code implemented by the ATHENA graphical interface. Fit of theoretical signal to EXAFS was performed by using the IFEFFIT8 code implemented by the ARTEMIS interface. Fitting of parallel and perpendicular polarization spectra was carried out simultaneously. This also improves the fit statistics allowing a precise determination of interatomic distances. The fits were restricted to the I and II coordination shells containing N_I = 12 and N_{II} = 6 Ni atoms respectively. The coordination numbers N_I and N_{II} where kept fixed to their crystallographic values. The fit parameters were: the origin of photoelectron energy, E_0, the in-plane interatomic distance for the I shell, $d_{I\text{-}in}$, the out-of-plane interatomic distance for the I shell $d_{I\text{-}out}$, the Debye-Waller factors for I and II shells,σ_I^2 and σ_{II}^2. The S_0^2

amplitude reduction factor was fixed to 0.7 for all the samples. For the E_0 best fit values differences lower than 0.5 eV were found for the different samples. The II shell interatomic distances $d_{II\text{-}in}$ and $d_{II\text{-}out}$ were defined in the fit as a function of $d_{I\text{-}in}$ and $d_{I\text{-}out}$ allowing tetragonalization of the cubic lattice. Fits were performed in *q*-space in the range 2.8-12.5 Å^{-1} on the $k\chi(q)$ signal obtained by Fourier Filtering of the Fourier Transformed $\chi(k)$ in the range 1-3.7 Å.

A typical fit obtained for one of the samples is shown in Fig.1 together with the correspondent Fourier Transform represented in Fig 2. The values of $\varepsilon_{//}$ and $\varepsilon_{\perp}$ were then calculated from the fit values of $d_{II\text{-}in}$, $d_{Ii\text{-}out}$ as $\varepsilon_{//(\perp)} = (a_{//(\perp)} - a_{Ni})/a_{Ni}$. The results are shown in Fig.3 where we represent $\varepsilon_{\perp}$ as a function of $\varepsilon_{//}$. The different colours of the dots represent different thicknesses of the Ni layers, and the labels correspond to the blocks number N. We also show as a line (dot-dashed line) the elastic behaviour $\varepsilon_{\perp} = -2(C_{12}/C_{11})\,\varepsilon_{//}$. As one can see, most of the samples points are not far from the elastic behavior and the strain content tends to decrease, as expected, upon increasing N. On the other side a few of them, corresponding to the thinnest Ni layers, deviate from elasticity showing reduced values of $\varepsilon_{\perp}$. An abrupt change looks to occurr changing from N=2 to N=3. This effect could be in principle due to a change in the elasticity constants never observed so far. We would like to check this results with further measurements for new samples with a thickness of 1 and 2 nm and with the same N values. To this end we presented a continuation proposal asking for six extra shifts to verify this result and complete the experiment.

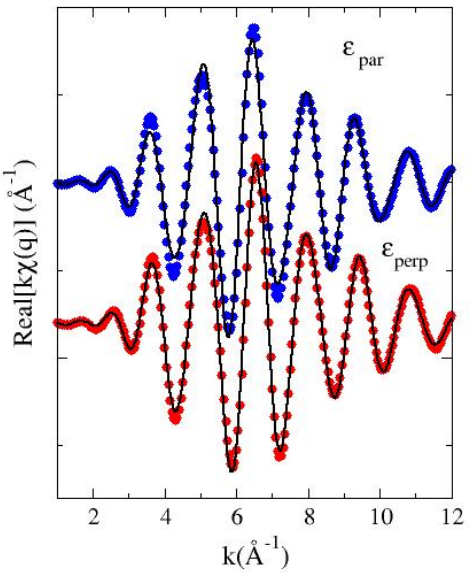

Fig.1

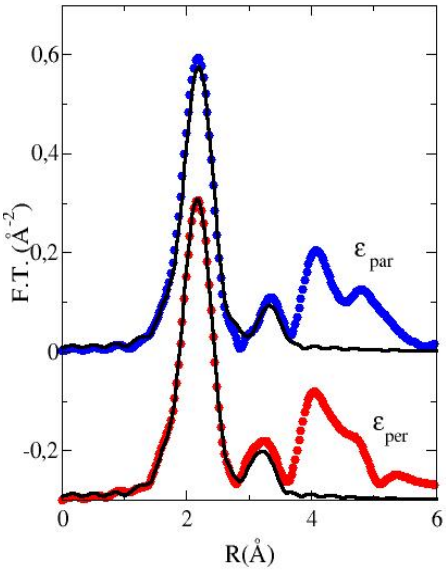

Fig.2

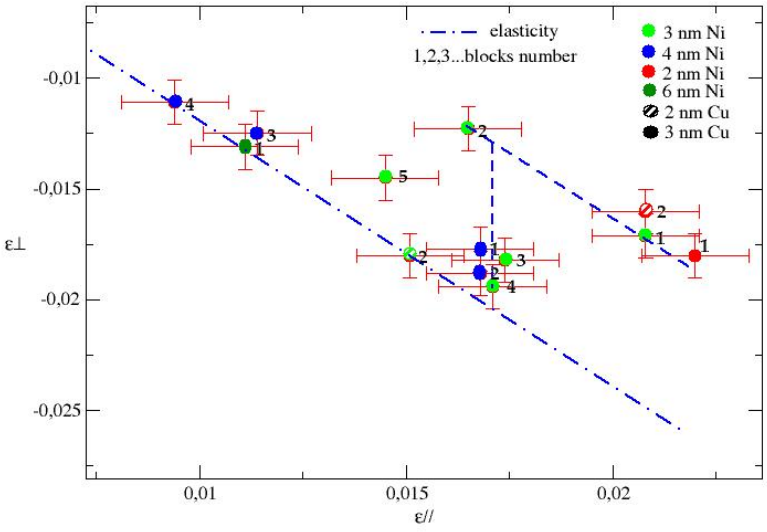

Fig.3

A further interesting finding is that the samples with t_{Ni}=4nm and N=1, 2 have a very similar strain content. For the samples with N equal to 3 and 4 the strain rapidly decreases as expected and the samples points move upwards along the elasticity line. This series of samples shows an interesting behaviour of the cohercive field H_c that varies abruptly when N changes from 1 to 2 without a change of the magnetic anisotropy constant. In our previous study we made an hypothesis about a blocking mechanism of dislocation propagation to the second Ni block[2,3]. Thus, in the framework of of rigid domain walls model[4] the statistical distribution of misfit dislocations does not change in the double film while the total driving force increases with the volume explaining the strong decrement of H_c. The EXAFS results provide a precise determination of the in-plane and out-of-plane strain in the Ni layers avoiding the interference of the Cu spacers, in particular in the determination of $\varepsilon_{//}$, and confirm our model. A paper is now in preparation[3].

References

[1] *Current-induced magnetization reversal in nanopillars with perpendicular anisotropy.* S. Mangin, E.E. Fullerton et al. Nature Mat., **5**, 210 (2006).

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