EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

ESRF

Experiment Report Form

ESRF	Experiment title: Can we measure the atomic magnetic moments with spin resolved photoemission?	**Experiment number**: HE1097
Beamline: ID08	**Date of experiment**: from: 7/11/2001 to: 13/11/2001	**Date of report**: 28/02/2002
Shifts: 18	**Local contact(s)**: Céline De Nadai	*Received at ESRF:*

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Original motivations and objectives of the experiment

We will refer to the experiment report of HE873 for the motivations of this new experiments. We just recall here that the aim was at measuring the atomic and orbital magnetic moments of pure ferromagnetic metallic films by using spin resolved x-ray photoemission spectroscopy. We wanted to test the validity and actual applicability of sum rules given by Thole and van der Laan on valence band photoemission spectra.

We have thus measured the photoemission spectra from the valence states (essentially the 3*d* electrons) of thin films of Fe, Co and Ni, epitaxially grown on a Cu(001) substrate. By conveniently combining the circular polarisation of the incident photons with the detection of the degree of spin polarisation of the photoelectrons, and by integrating the measured intensities over the whole set of final states, it should be possible to recover the actual value of $2\langle S_z \rangle$ (spin magnetic moment) and $\langle L_z \rangle$ (orbital magnetic moment).

The idea was to cross check the results of the sum rule analysis of photoemission spectra with the sum rule analysis of x-ray magnetic circular in $L_{2,3}$ x-ray absorption spectra (XAS). Both measurements could be made at remanence on the same samples, in the same geometry and in the same position.

Experimental results

We have prepared in situ and measured 6 different samples:

7.5 ML Co/Cu(001) in plane magnetised along <110> at remanence
8 ML Ni/Cu(001) magnetised along <001> at remanence
13.5 ML Fe/Cu(001) in plane magnetised along <110> at remanence
10.5 ML Co/Cu(001) in plane magnetised along <110> at remanence
13.5 ML Fe/Cu(001) in plane magnetised along <110> at remanence
10ML Ni/6 ML Co/Cu(001) in plane magnetised along <110> at remanence

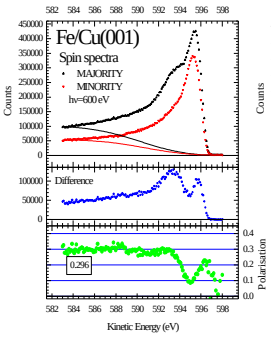
The moments derived from XAS, measured in total electron yield, give spin moments of 1.85 μ_B, 1.5 μ_B and 0.7 μ_B for Fe, Co and Ni respectively; and orbital moments of 0.03 μ_B, 0.11 μ_B and 0.07 μ_B for Fe, Co and Ni

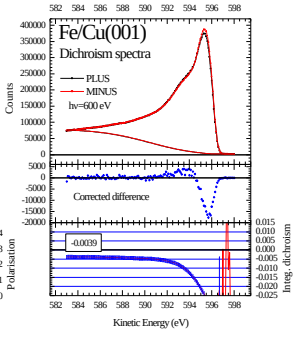
respectively. These values are uncorrected for possible signal saturation effects in the used geometry. The standard 6.6, 7.5 and 8.5 3*d* electron occupation numbers are assumed here for Fe, Co and Ni respectively. Those figures are compatible within ±20% with the published values for the pure, bulk materials under analysis. The fact that we find smaller values on our experiment can be easily ascribed to the fact that we have measured at remanent magnetisation and to saturation effects.

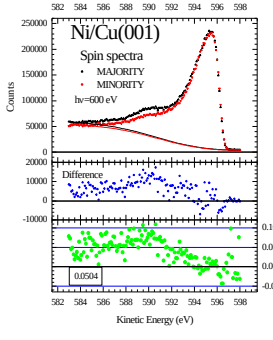
In the same experimental geometry we have measured the spin-resolved photoemission spectra for each sample. As already explained in the previous report, the two circular polarisations of the x-rays, the two spin orientations of the photoelectrons and the two possible orientations of the magnetisation (all taken with respect to the same axis, i.e. the photon propagation direction) give 4 inequivalent spectra. Those spectra can be diversely combined. By summing over the photon polarisations we get the traditional spin-resolved spectra of ferromagnetic materials. By summing over the two spin orientations we get the dichroism spectra. By summing over the two magnetisations we get the spin-orbit spectra.

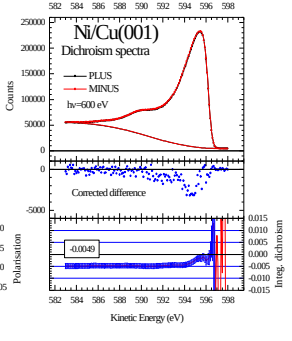
As one can see from the sample spectra shown in the figures below the overall data quality is excellent. The spin spectra reproduce nicely the results obtained at ID12B one year before, but with much better quality due to the ×6 gain in the photon intensity at ID08 with respect to ID12B. The improvement of the beam line performances allowed also the measurement of the dichroism spectra with sufficient accuracy. Very small effects are expected there due to the strong quenching of the orbital moment ($<L_z>$=0.03μ_B, 0.11μ_B , 0.07μ_B for Fe, Co, Ni): the integrated dichroism (difference/sum) over the whole 3*d* band is of the order of 0.004 to 0.009. This measurement is indeed rather difficult, and we expect the final results to have sizeable error-bars. Nevertheless we have been able to get reproducible results (different data sets on the same sample, different equivalent samples). Although the data analysis is far from been complete at present we can say that the values of $<L_z>$ obtained from the dichroism in photoemission reproduce those obtained from XAS within 0.01 μ_B. The spin moments derived from photoemission seem somehow more problematic. Using a standard data treatment, including a Shirley background, subtraction we obtain $2<S_z>$ values 30% smaller in photoemission than in XAS. This result is somehow surprising and represents the main question open concerning the presented experiment.

See figures in next page


Fe/Cu(001)
Spin spectra
MAJORITY
MINORITY
hv=600 eV
Counts
Difference
0.296
Polarisation
Kinetic Energy (eV)


Fe/Cu(001)
Dichroism spectra
PLUS
MINUS
hv=600 eV
Counts
Corrected difference
-0.0039
Integ. dichroism
Kinetic Energy (eV)


Ni/Cu(001)
Spin spectra
MAJORITY
MINORITY
hv=600 eV
Counts
Difference
0.0504
Polarisation
Kinetic Energy (eV)


Ni/Cu(001)
Dichroism spectra
PLUS
MINUS
hv=600 eV
Counts
Corrected difference
-0.0049
Integ. dichroism
Kinetic Energy (eV)