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A NIXSW and XAFS study of Fe nano-scale islands formed on N-precovered Cu(100) surface

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Experimental

We have performed an X-ray absorption fine structure experiment (XAFS) at the Fe *K*-edge on ID32. The aim of the experiment is to characterise the geometric structure of self-assembled Fe nano-particles epitaxially grown on the N-precovered Cu(100) surface as a function of both the Fe and N coverages. The XAFS experimental program illustrated in the proposal was successfully completed. XAFS data were acquired in total yield mode, at normal and grazing incidence, in the near edge and extended region (about 800 eV photon energy range), for Fe coverages ranging from 0.25 ML and up to 3 ML deposited onto five different N/Cu(100) substrate configurations i.e. clean Cu, 0.2 ML, 0.3, 0.4 ML, 0.5 ML (saturation) N pre-coverage. Some of the samples were prepared and measured twice to check the reproducibility. The Fe deposited onto clean and N-saturated Cu(100) substrates provides reference samples for the nano-structures that are formed at intermediate N pre-coverages. In fact, in the sub-saturation coverage regime N chemisorption gives rise to self-assembled arrays of islands of about 5x5 nm^2. These islands can channel the growth of other transition metals such as Fe, onto the remaining clean Cu(100) areas. By increasing the N pre-coverage from 0.2 to 0.3 ML the shape of the Fe nano-structures thus formed, evolves from stripes (average width 3 nm) to dots (average size 2x2 nm^2).

The quality of the XAFS data in terms of signal to noise ratio is excellent (see fig. 1) even for the most diluted samples. The time required to collect each spectrum was an average 20' which is an excellent performance for XAFS experiments.

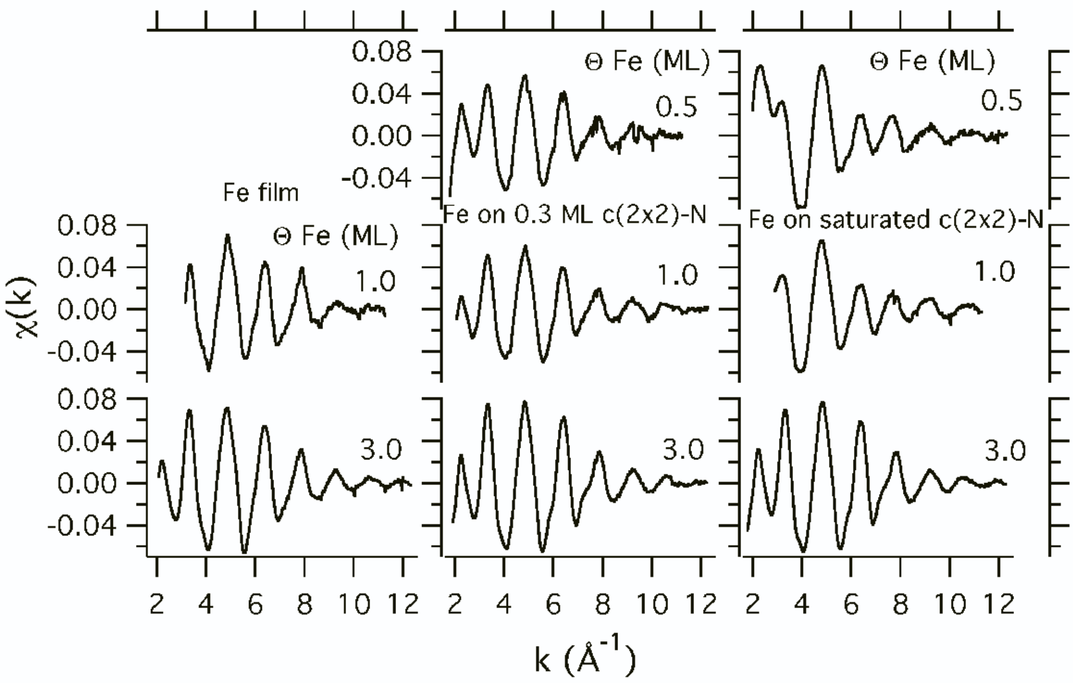

Fig. 1. Overview of the background subtracted EXAFS data.

Results and outcome

The first shell analysis of the EXAFS data shows results that are consistent with Fe nano-particles growing with an fcc/fct structure. This growth mode is similar to the one observed for Fe films on clean Cu(100). However, whereas Fe nano-structures or Fe films grown on clean Cu(100) form bi-

clean Cu(100). However, whereas Fe nano-structures or Fe films grown on clean Cu(100) form bi-layers even at the very low Fe coverage, Fe onto a saturated N/Cu(100) surface shows an initial growth in the shape of a mono-atomic layer.
The very high signal to noise level of the data, allows to perform also a multi-shell analysis. This type of analysis is still in progress and is being applied both to the near-edge (see fig. 2) and extended absorption data (see fig. 2). Up to five shells are required to model the experimental data. With the multi-shell analysis, differences between the Fe nano-structures and Fe grown on the N saturated Cu(100) become more evident. In particular, the low coverage glide distortion of the Fe layer on N-saturated Cu(100) observed with LEED [1] can be included in the model structure. These structural differences can be linked to the magnetic properties previously observed in photoemission for 2-3 ml Fe grown on sub-saturated N/Cu(100) [2]. In this high Fe coverage regime the Fe layer can be magnetised both parallel and perpendicular to the surface. This behaviour is at variance with the magnetism displayed by Fe layers of comparable thickness grown on clean Cu(100), where the easy axis is perpendicular to the surface. As a result of the present structural study, the apparent isotropic magnetism of Fe deposited onto the N precovered Cu(100) can be attributed to an actual 2D switching, over a nanometer-scale length, of the uniaxial anisotropy due to the non-uniform Fe epitaxial strain. At 2-3 ML thickness in fact, the Fe growth is no longer confined to the clean Cu areas outside the N islands and the Fe layer is partially in registry with the clean and partially in registry with the N covered Cu(100). Finally, according to our XAFS data, about 3 ML of Fe on N saturated Cu(100) are required to restore a Fe growth mode similar to the one obtained on clean Cu(100). It is interesting to note that once the Fe growth mode is restored magnetic moments parallel to the surface can no longer be observed as evinced by PE data.
The results have been presented in the form of a poster at the “surface and interface workshop” of the ESRF users’ meeting 2002.
The original proposal included a NIXSW to be carried out on extremely diluted Fe samples. This part of the program could not be carried out within the allocated time and we intend to resubmit it in the near future as a separate proposal.

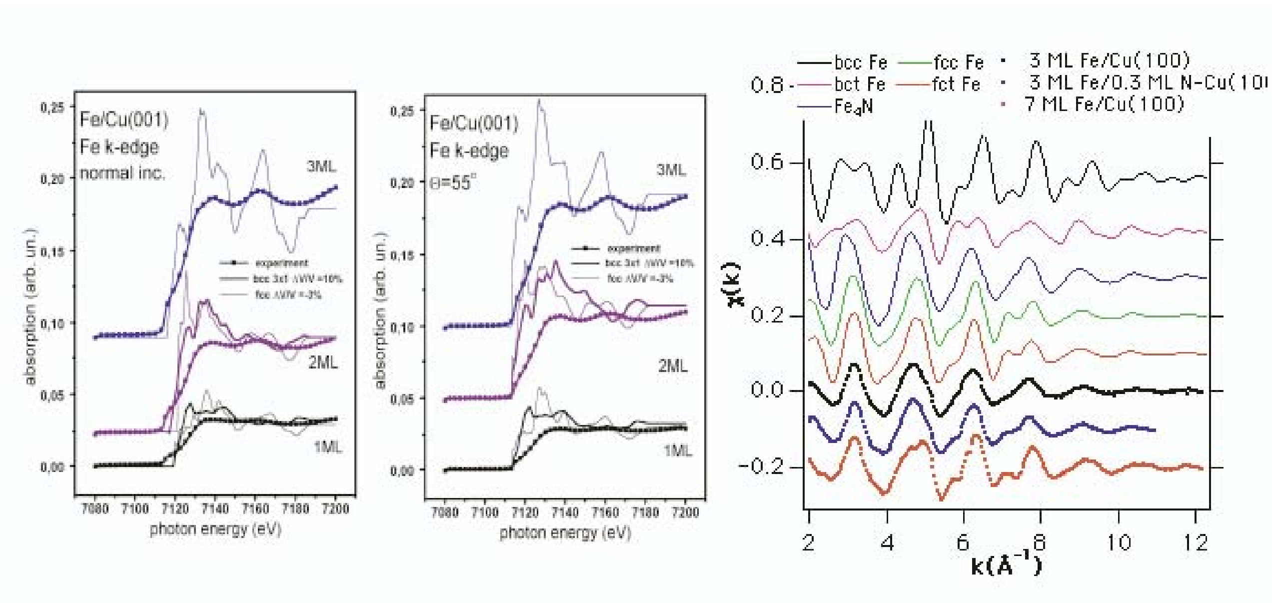

Fig. 2. Comparison between experimental data and multi-shell model data of the near edge and extended absorption region. See labels in the figures for details about the model structures.

References

[1] P. Finetti, R. Gunnella, S. D’Addato, to be published.

[2] P. Finetti, V.R. Dhanak, C. Binns, K.W. Edmonds, S.H. Baker, S. D’Addato, P. Finetti et al, J. El. Spectrosc. and Rel. Phenom. 114-116, 251 (2001).