Magneto-volume instability of $Fe_xNi_{(1-x)}$ films near Invar concentration

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INTRODUCTION

Magneto-volume instabilities in 3*d* transition metal films have been extensively investigated experimentally and theoretically. In epitaxial thin films, magnetic properties may change depending on the variation of different physical parameters such as thickness, temperature, growth conditions, structural transformations and composition. In bulk, $Fe_xNi_{(1-x)}$ alloys present an anomalous behavior for 65% *Fe* (Invar effect at $x = 0.65$). Ultrathin $Fe_xNi_{(1-x)}$ films also show magneto-volume instabilities, i.e., a clear dependency of the magnetization with the film composition [1]. Schumann et al. [1] have found for $Fe_xNi_{(1-x)}$ films on $Cu(100)$ a magnetic transition from FM "high spin" to FM "low spin" sensitive to the atomic volume. Recent results for *FeNi* alloys show that the Invar effect and the "high spin" "low spin" (HS-LS) transition compete for the different *FeNi* concentration and that for the Invar composition (at 65 % *Fe*), the contraction due to the HS-LS transition is bigger than this effect [2]. These results show that studies of fcc *FeNi* ultrathin films with different atomic volumes are highly desirable, and may indicate magnetic phases not yet considered. Aiming to contribute to the understanding of the relation between the magnetic instability and the atomic volume, in this work we investigate the magnetism of ultrathin $Fe_xNi_{(1-x)}$ films epitaxialy grown on $Cu_{90}Au_{10}$, a substrates which lattice parameter is 1.25% larger than the lattice parameter of pure copper, i.e., we explore the effect of a lattice parameter expansion on the magnetic properties of the films for different concentrations of *FeNi*.

EXPERIMENT

$Fe_xNi_{(1-x)}$ ultrathin films $(0.50 < x < 0.90)$ were epitaxialy grown on $Cu_{90}Au_{10}$ at a base pressure of $3.0\text{x}10^{-10}$mbar. The substrate and the *FeNi* films (always 6 monolayers thick) were characterized in situ by low energy electron diffraction (LEED) and photoelectron spectroscopy. The film thickness was controlled by the evaporation flux during deposition and latter checked by evaluation of the photoemission spectra. The composition of the alloy films was determined by the ratio between the area of the 3*p* photoemission peaks of *Fe* and *Ni* after correction by the relative sensitive factors for each peak and normalization by the *Fe* peak (Fig. 1).

The magnetic properties of *FeNi* films, with same thickness and different compositions, were determined in-situ by linear magnetic dichroism in the angular distribution of the photoelectrons(LMDAD) using a ultra high vacuum (UHV) system

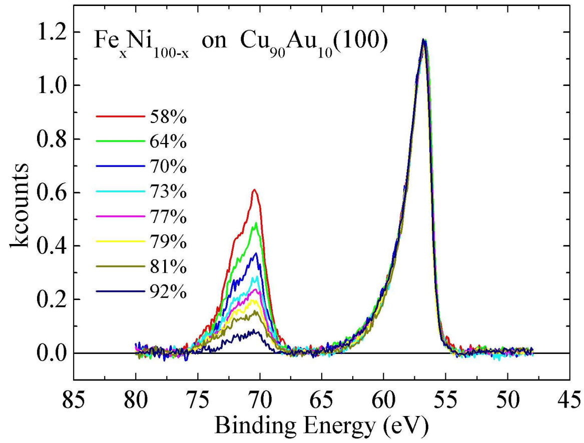

FIG. 1: *Ni* and *Fe* 3*p* photoemission spectra for the different *FeNi* films normalized to *Fe* peak.

coupled to the TGM beamline of the LNLS. The dichroic signal express the different selectivity of the absorption/emission for different polarization of the incident light. In the LMDAD this characteristic is, alternatively, explored by using linear incident light and magnetizing the sample in two opposite direction which is equivalent for using left and right circular polarization incident light. For each pair of photoemission spectra we have an asymmetry signal defined as $(I_{up} - I_{down})/(I_{up} + I_{down})$ Where I_{up} and I_{down} are the photoemission curves for the sample magnetized in each direction. In our experiment the $Cu_{90}Au_{10}$ substrate was mounted closing the gap of a small electromagnet in which, by reversing the electric current, it is possible to apply a magnetic field in two opposite directions perpendicular to the incident radiation plane(Fig.2). After cleaning by Ar^+-sputtering, the substrate was annealed at 600 K for surface reconstruction. Immediately after growth, the *FeNi* films were cooled to 160 K and the photoemission and LMDAD measurements were conducted. For a reasonable statistic, many pairs of photoemission spectra at opposite magnetization were collected.

RESULTS AND DISCUSSION

We have obtained good epitaxy of $Fe_xNi_{(1-x)}$ on $Cu_{90}Au_{10}(100)$. From the LMDAD results for the *Fe* 3*p* peak (Fig. 3), the high asymmetry (7%) observed up to at least up to 80% *Fe* indicate high magnetic moment for the Fe atoms (HS) [3], similar to the observed for $Fe_xNi_{(1-x)}/Cu(100)$ [1]. Above 80% *Fe*, the LMDAD asymmetry reduces abruptly. The *Fe*-

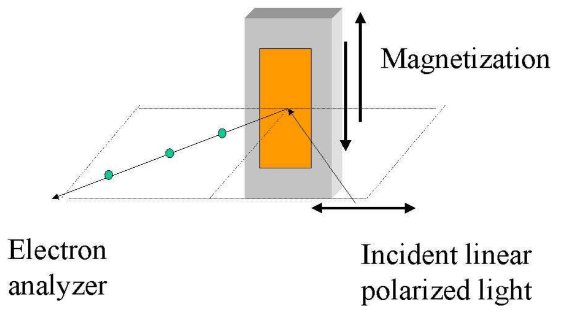

FIG. 2: LMDAD setup; the linear polarized incident light illuminates the sample which is magnetizing in two opposite direction. The asymmetry signal is obtained by the normalized difference of the originated pair of photoemission electrons spectra.

concentration in which it is observed a significant magnetic instability is clearly shifted to values higher than those obtained for $Fe_xNi_{(1-x)}$ on $Cu(100)$. The values of LMDAD asymmetry obtained above 80% Fe are also clearly higher than in case of $Fe_xNi_{(1-x)}$ on $Cu(100)$, suggesting that the expansion of the lattice parameter, due to the epitaxy, induces also an increase of the magnetic moment of the Fe atoms in the LS-state.

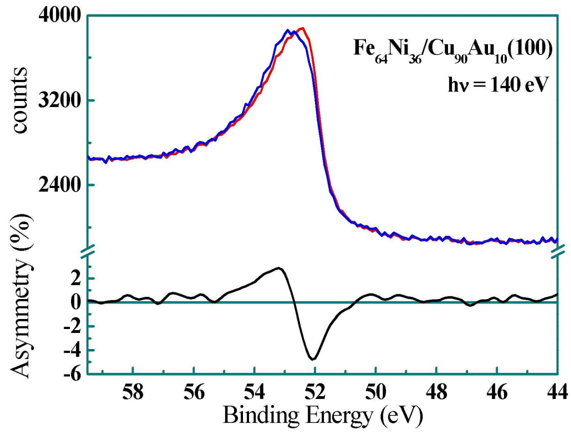

FIG. 3: Top curves: LMDAD photoemission spectra for the two magnetization directions of Fe 3p core level (red and blue lines), for a photon energy of 140 eV at 160K of temperature. Bottom curves: LMDAD asymmetry curve (black line)

CONCLUSION

This work seems to indicate that the magnetism - the critical concentration for the HS-LS transition and the magnetic moment of the LS-state - of ultrathin $Fe_xNi_{(1-x)}$ films is affected by the epitaxy on an expanded substrate, when compared to

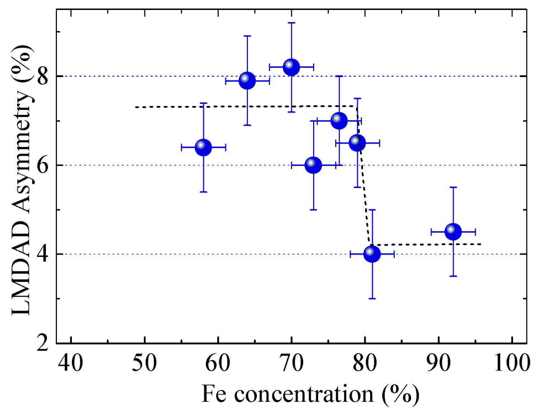

FIG. 4: Dependence with Fe concentration of Fe 3p LMDAD asymmetry at 160K, measuring using synchrotron radiation of 140 eV. The dashed line is guide to the eyes.)

$Fe_xNi_{(1-x)}$ on $Cu(100)$. It represents the first successful LMDAD experiment conducted at the LNLS and opens new experimental possibilities in this laboratory.

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