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Magnetic linear dichroism in photoemission from Fe on $Cu_{84}Al_{16}$(1 0 0) and Cu_3Au(1 0 0)

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Abstract

We have investigated the magnetic properties of monolayers of FCC Fe grown epitaxialy on $Cu_{84}Al_{16}$(1 0 0) and on ordered Cu_3Au(1 0 0), substrates that present lattice parameters 1% and 3.7% bigger than pure Cu. The magnetic measurements were carried out by linear magnetic dichroism in the angular distribution of photoelectrons (LMDAD), using linearly polarized synchrotron radiation. The LMDAD measurements of the Fe 3p core levels show that starting from 2.5 monolayers (ML) for Fe/$Cu_{84}Al_{16}$(1 0 0) and from 4 ML for Fe/Cu_3Au(1 0 0) these FCC Fe films present in-plane ferromagnetism. The 9% increase of the magnetic splitting of the Fe 3p LMDAD peak-to-peak asymmetry measured for Fe/Cu_3Au(1 0 0) suggests an increase of the Fe magnetic moment with increasing volume of the high-spin FCC Fe films.

Keywords: Surface magnetism; Dichroism – photoemission; Dichroism – linear magnetic; Thin films – epitaxial

Metastable FCC Fe is predicted to present a sensitive dependence of magnetic moment with atomic volume. FCC Fe films on Cu(1 0 0) has been intensively investigated and the complex correlation found between the magnetic properties and structure for these ultrathin films [1] can also be connected to the fact that Cu shows a lattice parameter very close to that expected for the magneto-volume instability for the 'high-spin' FCC Fe [2–4]. Ferromagnetic FCC Fe can be also stabilized on other FCC substrates and Fe on Cu_3Au(1 0 0) has been investigated by Mössbauer spectroscopy [5], MOKE [6,7] and LEED and electrons spectroscopies [8,9].

Recent experiments have shown that efficient measurements of magnetic dichroism in $l > 0$ core-level photoemission with synchrotron radiation are a powerful tool for atom-specific surface magnetometry, i.e., these technique can be used to measure relative changes of the surface magnetic moment in an atom-specific way [10,11].

In this paper, we study the magnetic properties of epitaxial ultrathin Fe films grown on bulk Cu_3Au(1 0 0) (CuAu) and on bulk $Cu_{84}Al_{16}$(1 0 0) (CuAl), FCC substrates that present lattice parameters 3.7% and 1% higher than pure Cu, respectively, and are therefore suitable to favor the stabilization of the 'high-spin' phase of γ-Fe. The magnetic properties of the Fe films obtained were determined by linear magnetic dichroism in the angular distribution of photoelectrons (LMDAD measurements) [10–12] in core-level photoelectron spectroscopy with linear-polarized synchrotron radiation (SR-PES) from the undulator beam line SU7 of the SuperAco storage ring at LURE. Fe monolayers (1–6 ML thick) were grown under MBE conditions onto clean surfaces of CuAl and ordered CuAu single crystals and characterized by SR-PES and by LEED. The Fe evaporation rate was typically 0.3 Å/min and the residual gas pressure during the Fe evaporation was always better than 8×10^{-10} mbar. Fe monolayers were prepared at

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RT on CuAu and at 150 K on CuAl. The LMDAD measurements were done by using the same experimental setup and geometry described in Ref. [11], where the electrons were collected along the sample normal with an angular acceptance of $\pm 22°$. In this method, the presence of magnetic dichroism in photoemission spectra is a direct evidence of long-range magnetic order in the top layers of the material and the energy splitting in the dichroism curve (asymmetry) is proportional to the magnetic moment [10]. We have measured the Fe 3p core level from the Fe monolayers and mirror experiments were achieved by aligning the in-plane magnetization of the Fe surface up or down along the vertical direction, perpendicular to the scattering plane. The magnetic (LMDAD) asymmetry is defined as $A = (I_{up} - I_{down}/I_{up} + I_{down})$, where $I_{up(down)}$ were the photoelectron spectral intensities obtained with the sample in the upward (up) or downward (down) directions. The pseudomorphic growth of FCC Fe monolayers on the CuAl and CuAu surfaces were confirmed by LEED and the flatness of the films were confirmed by the evolution of the PES peaks.

As illustrated in Fig. 1, we have found in-plane ferromagnetism starting from 2.5 ML FCC Fe on CuAl and starting from 4 ML FCC Fe/CuAu, the last result being in good agreement with Lin et al. for RT-grown films [6, 7]. Fig. 1a and Fig. 1b show the Fe 3p LMDAD for 2 and 3 ML Fe/CuAl, prepared and measured at 150 K, obtained with synchrotron radiation of 170 eV. Fig. 1c and Fig. 1d show the magnetic photoemission spectra at 150 K for 3.5 and 4 ML Fe/CuAu prepared at RT, obtained with photons of 150 eV. The clear LMDAD asymmetry observed in Fig. 1b and Fig. 1d reveal the in-plane ferromagnetism for these Fe monolayers. The absence of asymmetry found for Fe films thinner than 2.5 ML for Fe/CuAl and than 4 ML for Fe/CuAu (Fig. 1a and Fig. 1c) is presumably a consequence of perpendicular magnetization in the films, as observed by MOKE for Fe/CuAu [6, 7].

In Fig. 2 we compare the normalized Fe 3p LMDAD splitting at 150 K of BCC Fe(1 0 0), 3 ML FCC Fe on CuAl and 4.5 ML FCC Fe/CuAu. Since the width of the dichroism spectrum (difference) is proportional to the atomic exchange interaction for the 3p core hole, i.e., the observed magnetic splitting reflects the local magnetic moment of the excited atoms [10, 11], our results are evidences of high-spin FCC Fe, as observed by CMD on Fe/Cu(1 0 0) [13], and the variation of the splitting observed in Fig. 2 (9%) can suggest an enhancement of the magnetic moment in high-spin Fe/CuAu over that of BCC Fe and of FCC Fe/CuAl. These result are in qualitative agreement with those obtained from investigations with Mössbauer spectroscopy on Fe/CuAu [5] and on $Fe/Cu_{1-x}Au_x(1\,0\,0)$ [14].

In conclusion, we have observed in-plane ferromagnetism in FCC Fe(1 0 0) monolayers on $Cu_{84}Al_{16}(1\,0\,0)$ for thicknesses between 2.5 and 6 ML and also in FCC Fe monolayers on $Cu_3Au(1\,0\,0)$ for thickness higher than 4 ML. The increase of the magnetic splitting of the Fe 3p LMDAD peak-to-peak asymmetry measured for FCC Fe grown on $Cu_3Au(1\,0\,0)$ suggests an increase of the magnetic moment with increasing volume of the γ-Fe, as predict for magneto-volume effects in ferromagnetic 'high spin' FCC Fe.

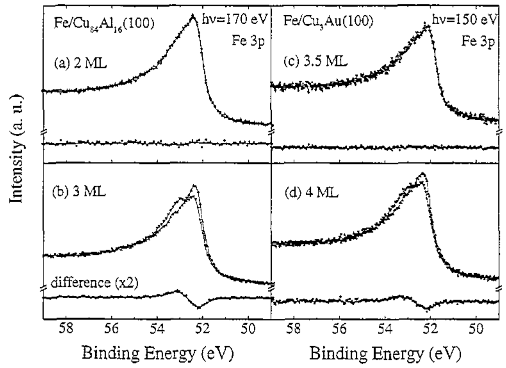

Fig. 1. Fe 3p LMDAD spectra at 150 K for (a) 2 and (b) 3 ML $Fe/Cu_{84}Al_{16}(1\,0\,0)$ and for (c) 3.5 and (d) 4 ML $Fe/Cu_3Au(1\,0\,0)$.

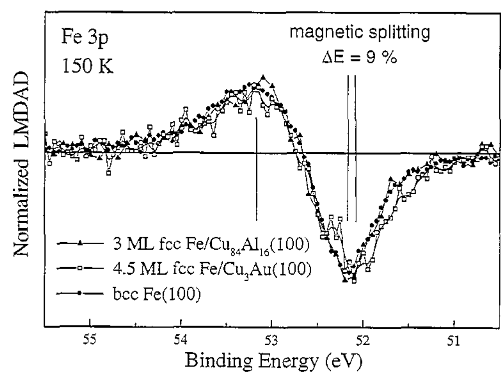

Fig. 2. Normalized Fe 3p LMDAD (at 150 K) for 3 ML FCC Fe on $Cu_{84}Al_{16}(1\,0\,0)$, 4.5 ML Fe on $Cu_3Au(1\,0\,0)$ and for BCC Fe(1 0 0). The curves are arbitrarily aligned on the same side of the asymmetry to better show the increase of the magnetic splitting.

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