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GROWTH AND SPIN STRUCTURE OF ULTRATHIN Fe FILMS ON W(110)

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We investigated structure and magnetism of uncovered ultrathin epitaxial Fe films grown on W(110). In addition to standard surface sensitive techniques we applied *in-situ* Grazing Incidence Nuclear Resonant Scattering of X-rays (GI-NRS) [1]. The GI-NRS is a synchrotron analogue of the Mössbauer spectroscopy. Recoilless excitations of the nuclear energy levels, split due to the hyperfine interactions, are involved and the hyperfine parameters can be derived from a characteristic beat pattern seen in the time evolution of the nuclear resonant scattering (time spectrum) [1]. Due to the high brilliance of the third generation synchrotron sources the method provides unique possibilities to probe magnetic properties with submonolayer sensitivity allowing one to accumulate a high quality time spectrum for one monolayer of ^{57}Fe film in a few minutes.

The experiment was performed in a multi-chamber ultra high vacuum (UHV) system (base pressure 1×10^{-10} mbar) at ID18 at ESRF Grenoble [2]. A special NRS scattering chamber, equipped with a ^{57}Fe electron beam evaporator, was mounted on a Huber goniometer, so that the time spectra could be collected simultaneously with Fe deposition. On the atomically clean W(110) single crystal ^{57}Fe films were grown at a rate of about ~0.12 Å/min, which was precisely calibrated using a quartz monitor and X-ray reflectivity. Two large diameter beryllium UHV windows allowed the incident and scattered X-ray beam to access the sample and an avalanche photodiode detector array, respectively. The grazing incidence angle (~3.8 mrad) was optimized for the maximum count rate of the delayed quanta.

First, 1.8 Å of ^{57}Fe, corresponding to 1.1 pseudomorphic monolayer (psML), was deposited at 500 K. Next, a series of room temperature deposition steps was performed, each one corresponding to evaporation of 0.4 Å, till 10 Å (~5 ML) of the total Fe thickness was reached. After each deposition step, a time-spectrum was collected at room temperature for *k* vector of the incident X-ray beam parallel to the [1-10] in-plane direction of W(110). The whole process of deposition and time-spectra accumulation took only 1.5 h, and therefore the residual gas adsorption effects were negligible. The GI-NRS data were fitted using the program CONUSS [3]. In Fig. 1, the measured time spectra are shown for selected Fe thickness. The spectrum of the 1.1 psML film shows no quantum beat

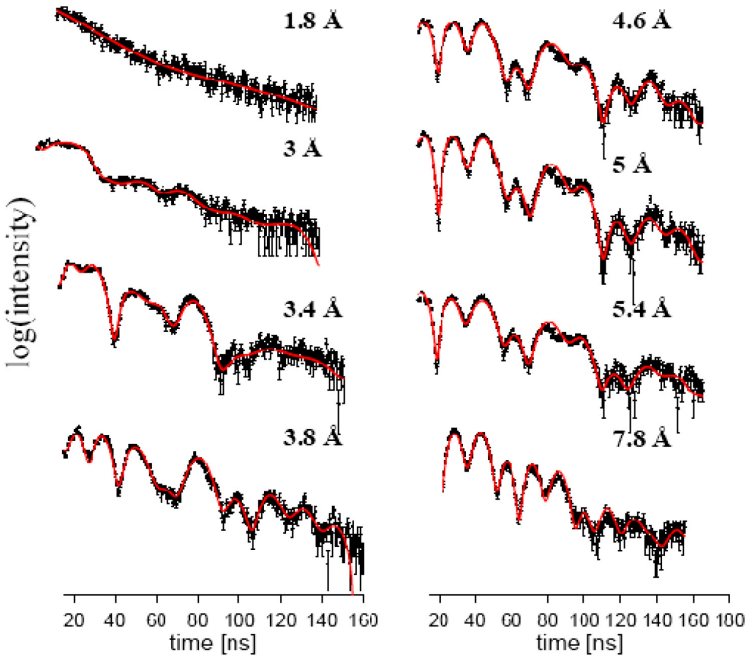

Figure 1. Fitted NRS time spectra for Fe/W(110) films of selected thicknesses.

pattern and could be fitted assuming a single paramagnetic site. The site is characterized by a distribution of the quadruple splitting due to the electric field gradient with the principal axis perpendicular to the surface. A quantum beat structure appeared in the time spectra when the nominal Fe thickness reached 3 Å, which corresponds to 1.8 psML. For coverage between 3 and 5.8 Å, analysis of the time spectra indicated a gradual transition from nearly perpendicular magnetization for 3 Å film to the in plane collinear magnetic order above 5.8 Å. For intermediate coverage a complex magnetic structure was derived from the numerical analysis. The magnetic structure is related to the film morphology characterized by a deviation from a layer-by-layer growth mode beyond the first monolayer. Competition of out-of-plane and in plane magnetic anisotropy for double layer Fe patches and for thicker Fe areas, respectively, leads to coexistence of non-collinear spin structures at buried layers, which could not be solved using traditional methods.

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References

[1] R. Röhlsberger, *Nuclear Condensed Matter Physics with Synchrotron Radiation*, STMP 208, (Springer-Verlag, Berlin Heidelberg 2004).

[2] S. Stankov, R. Rüffer, M. Sladecek, M. Rennhofer, B. Sepiol, G. Vogl, N. Spiridis, T. Slezak, J. Korecki, "An ultra-high vacuum system for in-situ studies of thin films and nanostructures by nuclear resonance scattering of synchrotron radiation", *Rev. Sci. Instrum* **79** (2008) 045108

[3] W. Sturhan, "CONUSS and PHOENIX: Evaluation of nuclear resonant scattering data", *Hyperfine Interact.* **125** (2000) 149–172.