DEPTH-RESOLVED MAGNETIZATION STRUCTURE AT THE SPIN REORIENTATION TRANSITION IN FE/W(110) ULTRATHIN FILMS STUDIED BY THE NUCLEAR RESONANT SCATTERING OF SYNCHROTRON RADIATION

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For almost two decades different Fe nanostructures deposited on W(110) have been one of the most intensely studied model systems in surface science. An in-plane spin reorientation transition (SRT) belongs to the most fascinating magnetic phenomena observed for Fe/W(110) ultrathin films [1]. During the film growth, when approaching the critical Fe film thickness, the magnetization switches from $[1\bar{1}0]$ to [001] in-plane direction. While the driving source of this transition, namely magnetic surface anisotropy, is well recognized its scenario is not fully understood. It is usually considered either as continuous magnetization rotation from $[1\bar{1}0]$ to [001] or as coexistence of the $[1\bar{1}0]$ and [001] oriented magnetic domains with different occupation. We used in-situ, Grazing Incidence Nuclear Resonant Scattering (NRS) of synchrotron radiation to monitor under ultrahigh vacuum conditions the thickness induced evolution of the spin structure of Fe(110)/W system. The measurements were done at the beamline ID18 at European Synchrotron Radiation Facility (ESRF) in Grenoble. NRS is a synchrotron analogue of Mössbauer spectroscopy (MS), in the sense that recoilless excitation (induced by the resonant x-rays with energy 14.4 keV for ^{57}Fe) of the nuclear energy levels, split due to the hyperfine interactions, is involved. In this method, the hyperfine parameters can be obtained from a characteristic beat pattern seen in the time evolution of the intensity of nuclear resonant scattering (the so called time spectrum) [2].

The present GI-NRS experiment allowed us to get insight into the mechanism of the in plane SRT. In a single experimental run, multiple transition steps induced by the film thickness could be studied. The ^{57}Fe was evaporated on the W(110) crystal held at 330 K with the rate of 0.3 ML/min to the final thickness of 30 ML. During the preparation, a set of NRS time spectra were collected (acquisition time per spectrum was only several seconds), thus probing the hyperfine parameters in 0.3 ML thickness steps.

NRS time spectra and corresponding theoretical fits at about 10 ML of Fe film thickness indicate domination of the film interior with B_{hf} = 33 T, uniformly magnetized al*ong* $[1\bar{1}0]$. Such a magnetization state persists up to above 20 ML. Around 25 ML, the beat pattern changes essentially and corresponds to a unique B_{hf} = 33 T along [001]. Assuming a homogeneous magnetization depth profile across the Fe(110) films, the following models were considered for the magnetization transition from $[1\bar{1}0]$ to [001]: (i) coherent rotation and (ii) decay to [001] oriented domains. Both models showed distinctly different spectra but, unfortunately, any combination of the magnetization configuration resulting from the models could give a satisfactory description of the NRS time spectra series in the thickness induced spin reorientation transition. Interestingly, when the depth dependent magnetization structure was assumed the perfect fits could be obtained indicating a more complex nature of the transition [3]. The non-collinear, exotic magnetic phase of epitaxial Fe films was found in the vicinity of a critical SRT thickness. Such a magnetic structure resembles a planar domain wall with its center propagating towards the surface as the thickness increases.

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