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Shifts: Long term	**Local contact(s)**: Dr. Salvador FERRER and Dr. Odile ROBACH	*Received at ESRF:*

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Report:

The aim of this long term project is the investigation of the correlation between atomic structure, mechanical stress and magnetic anisotropy in ferromagnetic monolayers. To this end we perform combined surface X-ray diffraction measurements, crystal curvature measurements and magneto-optical Kerr-effect (MOKE) experiments at the beamline ID-03.

An important aspect of our project is the direct measurement of forces in a growing film with sub-monolayer sensitivity. Simultaneous in-situ surface X-ray diffraction experiments elucidate the atomic structure. The results obtained by the combination of the two techniques are analyzed to study the stress evolution in ultrathin films starting from a sub-monolayer coverage.

The in-situ combination of crystal curvature measurements during film growth with surface X-ray diffraction has been successfully implemented at the ID-03 beamline. In this interim report we report on curvature measurements during growth of the first layer Ni on W(110). The Nishiyama-Wassermann growth of Ni on W(110) leads to a succession of different atomic arrangements in the first Ni layer with increasing Ni deposition [1]. This growth mode is characterized by a strong anisotropic misfit within the growing Ni film. Along W[001], the misfit amounts to 27 %, along W[110] it is only 3.7 %. In previous investigations based on low-energy electron-diffraction (LEED) and scanning-tunneling microscopy (STM) we have suggested pseudomorphic, 1x8- and 1x7- coincidence structures with increasing Ni coverage [1]. These structures lead to an increasing Ni packing density along W[001], which changes the Ni misfit along W[001] from 27 % over 13 % to a slight compression of –1.3 %, respectively. These structures are identified by the corresponding characteristic curvature signals. The curvature of the W(110) substrate is measured by our optical deflection technique and the diffracted X-ray intensity of a selected diffraction spot is recorded simultaneously during film growth, as shown in Fig.1. The curvature data obtained at the beamline ID-03 correspond to our previous stress measurements [1]. The curvature data were taken as a highly sensitive monitor of the Ni coverage. As shown in the upper curve of Fig. 1, the intensity of the (1,1.25,0.2) reflection grows with increasing coverage and reaches a maximum before it drops down to almost its background value for the completion of the first layer. We ascribe the intensity of this reflex to a relaxed 1x7 coincidence structure. We repeated the experiment for the (1,1.286,0.2) reflex, which is ascribed to the 1x7 coincidence structure, and we show the result together with the corresponding curvature data in the lower panel of Fig.1. We conclude that upon filling of the first Ni layer, a relaxed 1x7 structure reaches a maximal population at a coverage of 1.13 (coverage 1: 1 Ni atom per W surface atom). With further Ni deposition, the intensity of this reflections decreases and the 1x7 coincidence structure gains in intensity. A plateau of the reflected intensity of the 1x7 phase at the completion of the first Ni layer at a coverage of 1.29 is found. Both structures lead to the formation of satellite peaks of the diffracted intensity along the W[001] direction. X-ray diffraction data have been collected for both structures and a detailed structural analysis is currently performed. A transversal and horizontal shift of the positions of the Ni- atoms from a simple 1x7 coincidence structure is explicitly taken into account. First results indicate significant distortions with structural modulation amplitudes of order 0.4 Å for the Ni atoms, and 0.2 Å for the W substrate atoms. The correlation of the structural data with biaxial stress measurements is planned to elucidate the stress-strain relation on an atomic scale for the 1x7 coincidence structure.

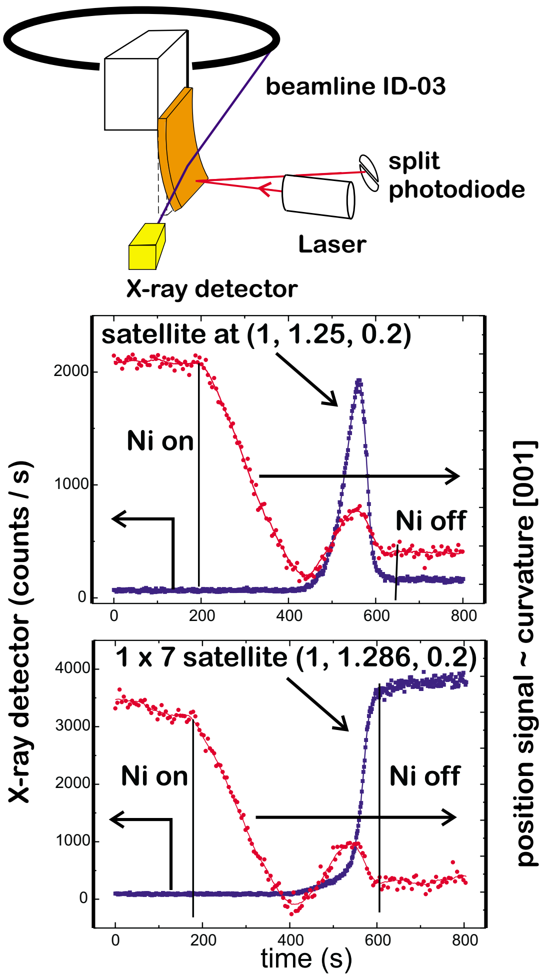

Fig. 1. Schematic of the curvature measurement at ID-03 by an optical deflection technique. Simultaneously taken curvature data –right axes – and X-ray diffraction data – left axes – during the growth of the first monolayer Ni on W(110). See text for details.

In the second part of our long-term project we investigated the correlation between the magnetic anisotropy of Fe monolayers on W(110) and the atomic structure of the Fe films. To this end combined curvature, MOKE and X-ray measurements were performed for Fe films of 5 ML and 10 ML thickness. The easy axis of magnetization of these films was in-plane along W[110], and it could be switched to W[001] after thermal annealing. Based on our previous work [2], the annealing induces the coalescence of Fe into islands which cover the first Fe layer. The annealing induces a reduction of the FWHM of the (1.1, 1.1, 1.1) reflection by a factor of four. The (1.1, 1.1, 1.1) reflection is ascribed to Fe in relaxed lattice positions with negligible lattice strain. The reduction of the peak width upon annealing indicates a higher population of Fe in Fe bulk-like sites and this correlates with a in-plane switching of the magnetic easy axis from [110] to [001], which is also the easy magnetization direction of bulk Fe. A detailed analysis of the structural data is under way, and we plan to extract information of the strain distribution within the Fe islands. From this analysis we expect to gain a deeper understanding of the driving force which causes the change of the magnetic anisotropy.

In conclusion, after two weeks of beam time of the long term project we have reached the experimental milestones as envisaged in our proposal. The coming beam times will be devoted to further combined magnetic and structural investigations, including the study of Ni-Fe multilayers on W(110), with special emphasis on the Fe induced change of the magnetic anisotropy of the Ni layers.

References:

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[2] D. Sander, Rep. Prog. Phys. 62 (1999) 809.