ESRF	**Experiment title: Spin Density Waves in thin Cr(100) films**	**Experiment number:** SI-315
Beamline: ID3	**Date of experiment:** from: 3.11.97 to: 13.11.97	**Date of report:** 24.2.98
Shifts: 21	**Local contact(s): S.** Ferrer	*Received at ESRF:* 02 MAR. 1998

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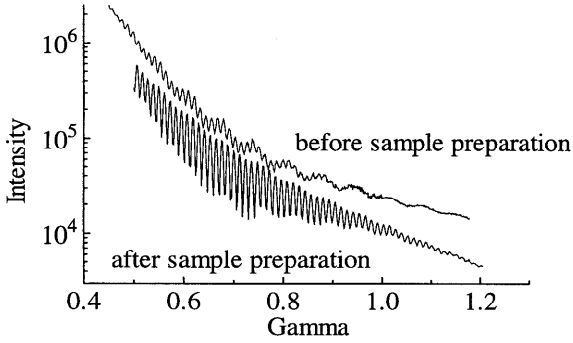
Report: In the first part of the experiment we examined if clean Cr(100) films with a thickness in the range from 200 to 300 nm show the same out-of-plane strain wave (SW), as it was observed on samples that were oxidized in air. The SW originates from the spin density wave (SDW), which modulates the magnitude of the Cr spins and is non-commensurate with the structural lattice. The sample was cleaned in the UHV end station chamber of ID3 by several cycles of sputtering and annealing to 900 K to remove the Cr-oxide overlayer. The sample cleanness was judged via the inspection of different crystal truncation rods (CTRs) and the specular reflectivity. All measurements were done at a photon energy of 14.514 keV. Fig.1 a) shows the specular reflectivity before sample treatment and afterwards. The much sharper film thickness oscillations are indicative for the smoothness of the film surface. From the short period oscillations the Cr thickness can be estimated to 210 nm and from the long period oscillations the thickness of the Nb buffer can be determined to 35 nm. Fig. 1 b) shows the (-11L) rods (non-integrated), before treatment and after treatment After sputtering the broad feature at L= 1.4 (probably due to an epitaxial oxide) disappeared and only a small modulation is left, which seems to be intrinsic for the clean surface. Unfortunately the CMA did not work, so that a cross-check of the sample contamination with Auger spectroscopy was not possible.



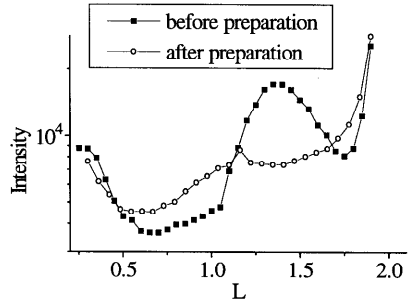


Fig 1 a) Specular reflectivity (Gamma: detector angle) b) (-11L) CTR before and after preparation

All measurements of the SW satellites were performed at 120 K. Measurements around the (01l), (022), (l-12) were performed in H, K, and L directions. The incident angle was fixed to 2°, because at this angle the whole Cr film is penetrated. The results are summarized in Fig. 2 for the (011) reflection. Around all Bragg peaks only satellites in the L direction are observed, in agreement with previous measurements from samples that were covered with a natural oxide layer.

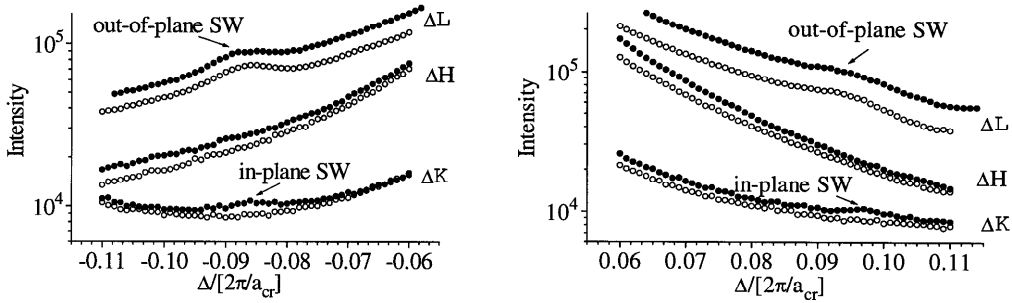


Fig. 2: H, K, and L scans around the (011) reflection (open circles: before Fe deposition)

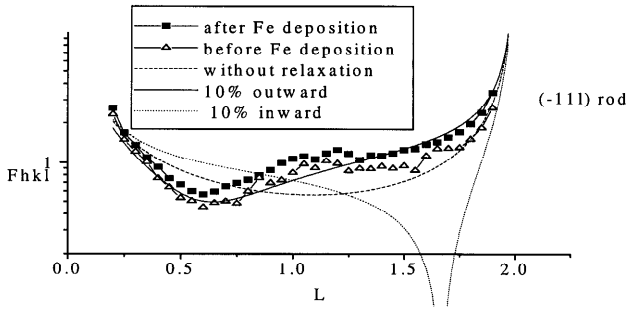


Fig. 3: (-11L) CTR and model calculations

In the next step of the experiment we tried to characterize as good as possible the structure of the clean Cr(100) film surface. Detailed structural information about the clean Cr(100) surface is still missing, because of the difficulties to prepare clean bulk Cr surfaces. We measured the integrated intensities of (0lL), (02L), (-11L) and (-12L) CTRs at room temperature. In Fig. 3 the measured structure factors of the (-11L) rod are given (open triangles). In addition different model calculations are plotted. The measured CTR shows a clear deviation from the structure factor of a Cr(l00) bulk termination without relaxations (dashed line in Fig. 3). On the other hand an outward relaxation of 10% of the first layer (structure factor solid line in Fig. 3) shifts the minimum of the calculated CTR in the experimentally observed position. In contrast inward relaxations (calculation dotted line in Fig. 3) of the first layer shift the minimum of the CTR to the right of the mid position. This trend holds also for the other CTRs measured, which are not shown here. Of course more quantitative calculations are necessary to refine the structural model and probably several layers are involved in the relaxation. An outward relaxation of a transition metal surface is a rather uncommon phenomena, since mostly inward relaxation is preferred. In the case of Cr(l00) surfaces theoretical calculations and experiments reveal an enhancement of the magnetic moment of the first layer to 2.7 muBor per atom, compared to the average value of 0.7 muBor in the volume. The enhanced magnetic moment of the near surface atoms is accompanied by an increased consumption of space, which could explain the observed outward relaxation. In the last step of the experiment we deposited Fe via e-beam evaporation on the Cr(100) surface. The structure factor along the (-11L) CTR after deposition on l-2 monolayer (ML) Fe is shown in Fig. 3. Because there is only a lattice mismatch of 0.5% between bcc Fe and Cr pseudomorphic growth occurs a this Fe thickness and the observed increase in the structure factor is due to the increase of 2 electrons, when passing from Cr to Fe in the surface layer. The modulation of the rod is still present and further quantitative analysis is necessary to understand the atomic structure of the Fe/Cr(100) interface. The H,K,L scans around the (011) reflection after l-2 ML Fe deposition are plotted a filled circles in Fig. 2 (filled circles). Already at this Fe thickness the magnetic structure of the whole Cr film starts to be influenced and a weak SW in-plane satellite begins to appear in the K direction. In the H direction still no satellites are observed, because of the selection rules involved. The final goal of the experiment would have been to follow the increase of the in-plane SW satellite for thicker Fe layers, because we know from 2 nm thick Fe cap layers, that only the in-plane SW satellite is observed and the out-of-plane satellite is completely suppressed. Unfortunately the measurements could not be done because the synchrotron was shut-down 5 shifts earlier than planned, because of technical problems.