ESRF	**Experiment title:** Dynamic Self-Organization of Nanoscale Gratings in Sputter Ablation	**Experiment number**: SI-489
Beamline: ID-3	**Date of experiment**: from: 20/9/1999 to: 26/9/1999	**Date of report**: 28/2/2000
Shifts: 18	**Local contact(s)**: Salvador Ferrer	*Received at ESRF:*

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Report:

Using grazing-incidence diffraction (GID) and grazing-incidence small-angle scattering (GISAXS) we performed a first in-situ and real-time study of the development of the morphology of the Ag(110) surface during sputtering at various surface temperatures. The sample had been characterized extensively by previous STM experimenents [1]. It was found that the Ag(110) surface develops a ripple morphology in accord with its two-fold symmetry and very anisotropic diffusion constants along the two high-symmetry directions [1,-1,0] and [001]. At low temperatures (100K to 240K), the ripple wave vector q_R is oriented along [1,-1,0], whereas at higher temperatures (280K-320K) q_R is pointing in [001]. Inbetween a regime is found with ripples along both directions. At temperatures above 320K, ripple formation does not occur any more. These findings can be interpreted by the anisotropic diffusion and two different Schwoebel barreers: At low temperatures only the fast diffusion determines the morphology. In the high-temperture, fast diffusion can overcome the respective Schwoebel barreer and the morphology is due to the slow diffusion. Hence Ag(110) offers the fascinating possibility of studying, how competing diffusion processes and Schwoebel barreers shape the surface during sputtering. The effect also offers the possibility to selectively produce nanostructures on surfaces which was recently demonstrated by creating regularly spaced InAs quantum dots on a GaAs substrate [2].

The drawback of the STM method is that samples have to be queched rapidly for each snapshot of the surface morphology, and that there can be some re-ordering during the quench. Therefore we wanted to perform complimentary x-ray scattering experiments to study the dynamics in-situ and in real time at ID3's UHV surface diffractometer. For studies of the dynamic we used GISAXS which provides direct information on the average ripple vector q_R as a function of sputter time, surface temperature and ablation rate. Moreover, information on the size distribution and the shape of the ripples is also contained in the detailed shape of the spectra. Fig. 1 shows series of GISAXS spectra taken at 160K in which the ripple period $L=2\pi/q_R$ changes from 250Å to 350Å with a scaling exponent of 0.11.

Furthermore we studied the surface morphology at late times using rod scans in both high symmetry azimuths. The truncation rods show a split in direction of q_R. From these we can determine average slopes of the cossresponding facets of 6° to 12° depending on surface temperature. These slopes compare very well to our earlier STM results (Fig.2). It appears that there is hardly any central compomnent in the rods indicating that the surface ripples have a sinuisoidal or even triangular shape.

So far, all initial measurements were performed with a scintillation detector and slits, limiting our time resolution to the scale of several minutes. In order to access the sec time scale we plane to use a 1D gas detector or a 2D CCD camera for the measurements to come. A 1D detector has advantages in line-up, since the GISAXS scans are close to the direct beam, and the specular reflection can be suppressed by appropriate collimation. Our future studies will be devoted to comparing sputtering and growth. Another interesting effect to study would be extrinsic shaping of the surface by an ion beam impinging at grazing angle to the surface. In this case the ripple will be either parallel or perpendicular to the ion beam irrespective of the surface orientation. For Ag(110) this effect can only be studied at very low temperatures, so for these studies we would use the similar Cu(110) surface. In-situ studies of sputtering and growth offer very detailed insights in surface dynamics, the understanding of which will be invaluable for using these effects to create self-organized nanostructures.

References

[1] S.Rusponi, C.Boragno and U.Valbusa, Phys. Rev. Lett. 78 , 2795 (1997); S.Rusponi, G.Costantini, C. Boragno and U. Valbusa, Phys.Rev.Lett. , 81 , 2735 (1998); S.Rusponi, G.Costantini, C. Boragno and U. Valbusa, Phys. Rev. Lett. 81, 4184 (1998).
[2] S. Facsco et al., Science 285, 1551 (1999).

Figures

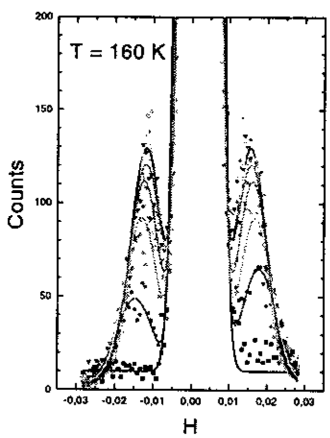

Fig. 1. Time evolution of the ripple morphology as indicated by the amplitude of the GISAXS signal during sputter ablation at 160K. Time between the shown scans is about 10min.

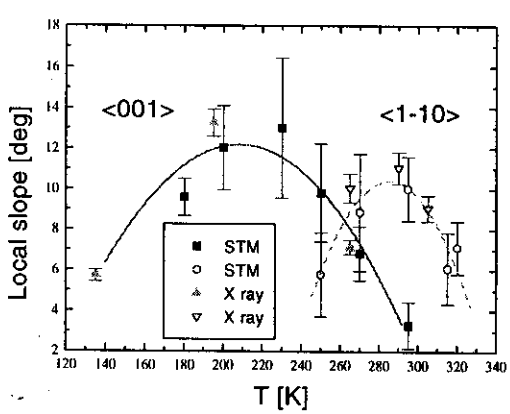

Fig. 2. Comparison of the values of the local slope for both high-symmetry azimuths as determined by STM and from rod scans.