# MODIFICATION OF THE ISLAND MORPHOLOGY DURING METAL EPITAXIAL GROWTH, DUE TO A SURFACTANT

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*During the epitaxial growth process of metals or semiconductors, the deposited material forms islands. In order to control this process, it is important to determine parameters such as the dimensions, shapes and densities of the islands. Two-dimensional images show that the island morphology and orientation can be modified by the addition of a surfactant before growth.*

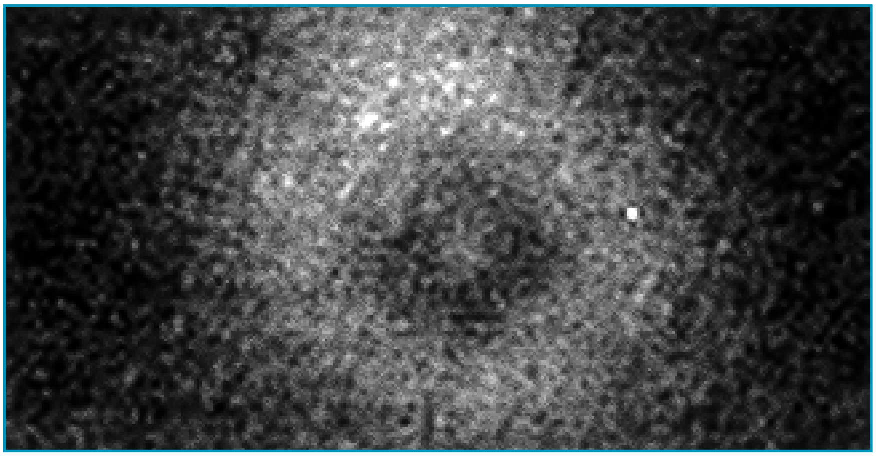
Generally speaking, epitaxial growth of metals or semiconductors aims to produce thin films as perfect as possible. This means good crystallinity, low density of defects and surface flatness. In many cases, if the substrate temperature is not too high, the deposited material forms islands at the surface causing significant surface roughness. The dimensions of the islands, their shapes and densities are very important parameters to determine, in order to control the growth process. The morphology of the islands is the result of the competitions of various dynamical processes. Thus, it is important to characterize the morphology during uninterrupted growth, since interruptions could cause further morphological changes.

The diffracted intensity from a rough surface contains information on the short-ranged correlations of the surface. By setting the scattering conditions in an adequate way, one may enhance the diffuse scattering which arises from the surface roughness relative to the long-range order part of the diffracted intensity. We have used a CCD camera to obtain two-dimensional diffuse scattering distributions of the diffracted intensity during uninterrupted epitaxial growth at the Surface Diffraction beamline (ID3).

Atoms of silver were deposited on Ag(100) at a constant rate of about one atomic layer per minute. The diffuse scattering at an early stage of growth when only 0.5 atomic layers were deposited is shown in Figure 1. The image was acquired in 3.7 seconds and it represents a snapshot of a long series of images acquired during the growth process. The diameter of the ring-shaped diffuse intensity provides information on the island sizes and separation. The circular symmetry of the intensity distribution indicates that no azimuthal ordering of the islands takes place at this stage. After further growth, the ring-shaped intensity changes to a four-fold symmetric distribution indicative of relative ordering of the orientation of the islands. Figure 2 shows the result after 27.5 atomic layers have been grown. In this case the image has been taken with a long exposure time (12 minutes) for better clarity of the figure but a snapshot of a few seconds already shows the cross-like intensity distribution of Figure 2. The arms of the cross are along the closest packed lines of substrate atoms. The diffraction pattern is indicative of a pyramidal island morphology.

A manipulation of the morphology of the islands may be done by depositing a small amount (~ 0.1 atomic layer) of a surfactant (Indium in our case), prior to the growth process. The atoms of the surfactant may act as nucleation centres of the islands or enhance surface diffusion, modifying their density. Figure 3 is an image taken after depositing 10.5 atomic layers of Ag on the Ag substrate pre-covered with In. Again, as in Figure 2, the image has been taken with a relatively long exposure time (5 minutes) for clarity. The scales of Figures 2 and 3 are the same. As may be seen, the spread of the diffuse scattering is less in Figure 3 than in Figure 2, indicating that the dimensions of the islands are larger in the case of growth with surfactant. The diffuse intensity shows also a four-fold symmetry indicative of a regularity of the island

*Fig. 1: Two-dimensional image of the diffuse scattered intensity during the growth of Ag on Ag(100) at the early stages of the deposition when only 0.5 atomic layers have been deposited. The image was acquired in 3.7 seconds and it represents a snapshot of a series of many images recorded during the growth process. The ring-shaped pattern indicates azimuthal disorder.*



morphology. However, both the shape and the orientation differ markedly from those obtained without surfactant. The symmetry axes of the intensity distribution in Figure 3 are rotated 45 degrees compared to those in Figure 2, indicating that the surfactant has caused the pyramid-like islands to grow in a different orientation. The bases of the pyramids are in this case aligned with the [100] surface directions which consist of lines of atoms separated $\sqrt{2}$ times the nearest neighbor atomic spacing. It appears that in some way the surfactant facilitates surface diffusion along the above directions.

The above examples illustrate how two-dimensional images may reveal very important information that would be inaccessible if only one-dimensional intensity profiles were recorded. ■

*Fig. 2: Diffuse scattering distribution after deposition of 27.5 atomic layers.*
*A four-fold symmetry is an evident indicative of ordering.*

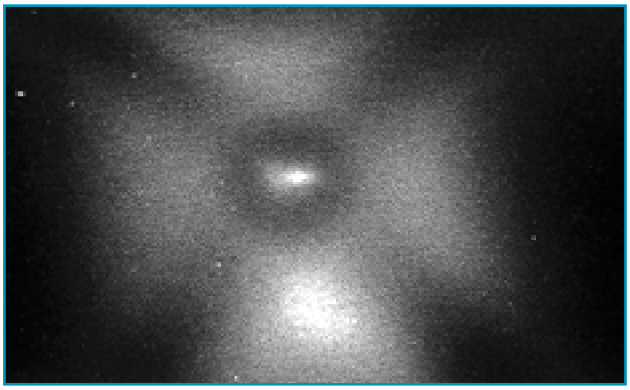
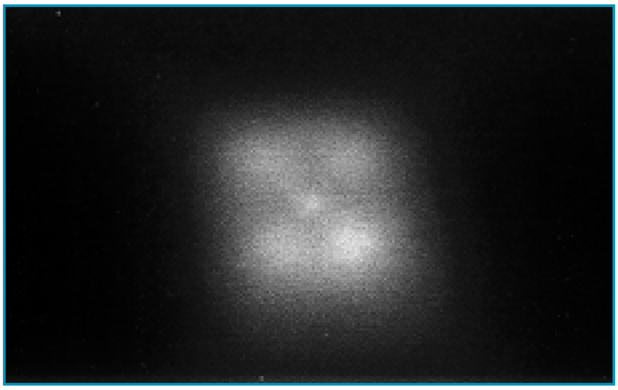


*Fig. 3: Diffuse scattering distribution after deposition of 10.5 monolayers of Ag on a Ag(100) surface pre-covered with a small amount of In. The image shows again a four-fold symmetry but the axes are rotated 45° compared to those in Figure 2.*



# OXIDATION OF NIAL(100) STUDIED WITH SURFACE SENSITIVE X-RAY DIFFRACTION

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*Thin, ordered aluminium oxide layers play a very important role as supports for model catalysts prepared under UHV conditions. Oxidation of NiAl single crystals provides an elegant way to prepare ordered $Al_2O_3$ layers, which can have different structures depending on the orientation of the NiAl substrate. In addition NiAl is frequently used as a high temperature resistant material. The formation of the protective $Al_2O_3$ layer is not understood in detail and a microscopic picture of the oxidation process is still missing.*

GEED investigations [1] show a (2*1) superstructure after high temperature oxidation and from additional EELS measurements the formation of θ-$Al_2O_3$ was deduced. The aim of our study was the determination of the $Al_2O_3$ layer structure and the structure of the $Al_2O_3$/NiAl(100) interface using surface sensitive x-ray diffraction. The clean sample surface was prepared in the *in situ* UHV surface diffraction chamber of ID32 by several cycles of oxidation and flashing to 1150 °C, which removes the oxide layer and other impurities. Figure 1 shows the structure factor of the clean NiAl(100) surface truncation rods as a function of the reciprocal lattice co-ordinate L normal to the surface.

We tried different models to simulate the data. In model 1 the ideal Ni bulk