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ESRF

Report:

Molecular Beam Epitaxial growth is one of the major techniques of material research and one of the most refined methods to growth thin films. A large research effort both experimental and theoretical has been done in the last years to understand the dynamics of the growth process. Two characteristic lenghts can be defined in a growing film: the surface roughness of the growing film , w , and a correlation lenght L parallel to the surface. Theoretical works show that they follow scaling relations resulting in power laws w ~ t ^B and L ~ t ^β/α being t the growing time [1]. The values of the exponents are different for different growth models. Recently, a result by Villain [2] pointed out that the existence of a Shwoebel barrier that prevents adatoms to diffuse down to a lower level terrace, may cause an instability in a singular surface leading to the formation of mounds with a characteristic lateral dimension L. A number of experimental studies by HRLEED, STM and He diffraction [3] have provide numerical estimates of the scaling exponents and verified the prediction of Villain. In all cases however, the growth was interrupted during a period of time in order to take the measurements. This interruption deviates the experiment from the theoretical calculations of growth and may cause an undesired evolution of the surface even if precautions are taken to avoid it.

By taking advantage of the intense flux at ESRF we have performed uninterrupted growth experiments on Ag(100) homoepitaxy at different temperatures. The results provide an unprecedent detail of the growth dynamics.

The experimental technique consists in recording transverse intensity profiles during growth with a binned CCD camera (exposure time 2 s. per profile).The incoming and exit beam are grazing me surface and the scattering geometry is such to stay in a minimum of a crystal truncation rod. As illustrated in figure 1 which shows several of these profiles taken during growth (rate: 90 s/atomic layer) the curves consist in a central peak representative of the long range surface correlations and a diffuse contribution consisting in two symtrically located broader peaks around the central one, which are characteristic of short range correlations [4].

Deconvolution of these profiles into their components evidences the familiar intensity oscillations of the intensity of the central peak as a function of deposition time and the less familiar oscillations of the diffuse intensity which are retarded 0.5 layers from the first ones.The separation of the diffuse component from the central peak is directly proportional to $1/L$ being L the characteristic surface length (as for example the mounds dimension).

By adjusting the experimentally determined values of L to a temporal power law, one finds inmediately β/α. Figure 2 shows an example of the exponents at different temperatures. The data points correspond to the coverages where the diffuse components am. more intense and the accuracy of the deconvolution is highest. Our data nicely agree with an important result published very recently [5]: it appears that the lateral characteristic length scales at the surface are already established just after coalescence of submonolayer islands.

We have modeled the growth with a set of rate equations describing the temporal evolution of the different surface levels. In the equations the interlayer transport is directly included. The solutions give a distribution of surface levels from which one may calculate the intensity of the central peak. The results agree very well with the measured intensities which give us confidence on the correctness of the method. From the level distribution as a function of time, one may evaluate the rms surface roughness or surface width w. Figure 3 shows some examples. The temporal evolution of the average value of w gives the exponent β as shown in the figure. The values of these exponents compare to recent simulations [6] and provide information on the importance of the Shwoebel barrier in the growth.

Similar measurements were performed with manipulated growth experiments (with surfactant and ion-assisted).

These results are being analysed and will be submitted for publication shortly.

Refs.

1.- See for example M. Kardar et al, PRL 56,889 (1986), J.M. Kim et al. PRL 62.2289 (1989)

2.-J. Villain, J. Phys. I, 119, (1991)

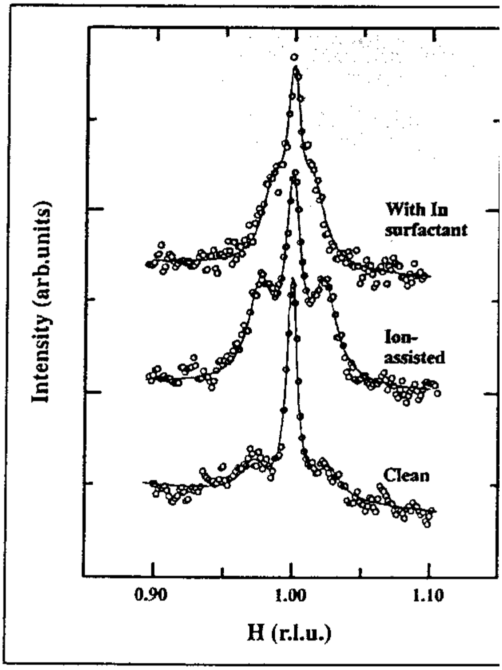
3.- Y. L. He et al. PRL 69,377O (1992), H. J. Ernst et al. PRL 72,112 (1994) M. D. Jhonson et al, PRL 72,116 (1994), J. A. Stroscio et al. PRL 75,4246 (1995), K. Thurmer et al. PRL 7.5, 1767 (1995)

4.- For more details see : J. Alvarez et al. ESRF Newletter, January 1996, pg. 8

5.- L. C. Jorristsma et al. PRL 78,911 (1977)

6.- J. G. Amar et al Phys. Rev. B 54, 14742, (1996)

Figure 1:



Transverse profiles of the diffracted intensity recorded during non-interrupted epitaxial growth experiments. Each profile was recorded in 2 seconds of exposure to the beam. The readout time was 1.3 second. Three different profiles have been chosen to illustrate how the diffuse scnttering may be different depending on the growth conditions (see text for details).

Figures 2 and 3 in the back side