ESRF	**Experiment title:** Crystal structure of compact surface-supported Co nano-clusters on Ag(111)	**Experiment number**: SI1670
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Motivation and summary

The buffer layer assisted growth (BLAG) allows to produce nanostructures on surfaces with a large variety of densities and sizes, from metal films to single nanoclusters [1]. A physisorbed rare gas is used to suppress the tendency towards epitaxial growth of a material B when directly deposited on a substrate A.
The aim of experiment SI1670 was to investigate the crystal structure and growth dynamics of Co nanostructures in the mono- and sub-monolayer coverage regime during the buffer layer assisted growth. Surface diffraction and scattering were performed during the whole BLAG process for Co/Xe/Ag(111) systems. The results in the thick (full decoupling from the substrate) and thin (partial coupling) rare gas layer limit have been investigated and results are shown here, explaining how, in the case of a surface-mediated BLAG, the growth of Co follows very different modalities.
The experiment was successful in showing details of the dynamics during the BLAG process with surface diffraction and scattering tools. It provides important information on nanocluster morphology but also limits of metal-physisorbed interfaces using the Weaver method.

Experimental

ID03 is equipped with a UHV chamber for in-situ sample preparation down to 20K. The Ag(111) was prepared by standard ion bombardment/annealing cycles, the cleanliness being verified by the CTR. Xe was adsorbed on a clean Ag(111) and verified by reflectivity. Co was deposited by thermal evaporation directly on the Xe buffer layer at low temperatures (20K-30K). The Co flux (0.03ML per minute) was calibrated by measurements of the reflectivity vs time. GIXRD and GISAXS experiments were done after each of the following BLAG steps: Xe adsorption at 20K, low-*T* Co deposition, desorption of the Xe multilayer at *T*=55K and stepwise annealing up to RT. Annealing of the film up to 55K leads to desorption of the bulk Xenon and growth in size of the Co grains. The last Xe monolayer is desorbed at 120K due to the stronger bond between Xe atoms and the Ag-substrate. Above this temperature the Co is in full contact with the substrate.

Results

1) ML amount of Co: from δ-scans and reflectivity curves we have studied the in-plane and out-of-plane morphology of the Co, specifically grain size, structure and characteristics of the interfaces Co/Xe, Xe/Ag(111) and then Co/Ag(111) after Xenon desorption. In Fig. 1(a) the deposition of 2ML Co (magenta coloured data) on the Xe film produces a drop of the intensity of the Xe peak at $\delta = 27°$ but an increase of the

peak at lower values δ = 16°, that could indicate a rearrangement of the Xe layer structure. From a multi-gaussian fitting of the spectral line shape we can conclude that Co on Xe has both cubic and hexagonal phases with the former being more abundant. Together with Xe desorption, the peak corresponding to the cubic phase becomes narrower (larger grains) whereas the hexagonal phase is unchanged. This could be an indication that the hexagonal phase corresponds to the percentage of Co that sinks in to the Xenon layer, attracted to the metal by Van der Waals forces. Reflectivity curves in Fig. 1(b) show the crystalline ordering of the Xe(111) film, especially after annealing at 30K (cyan curve). The high order is destroyed upon deposition of Co (magenta curve), as we can see from the damping of the oscillations intensity. From the increased periodicity of the oscillations we can also infer that the Xe film became thinner during Co deposition. This effect could be explained by hot Co atoms impinging on the surface that locally increase the temperature of the Xe film and therefore triggers Xenon desorption.

2) Submonolayer coverages of Co: from GISAXS we have monitored the growth dynamics of Co nano-structures on thin and thick Xe films. The Porod's law provide information on systems which are composed of two phases with different density. In this case the small angle scattering intensity follows a power law whose exponent depends on how the two phases are separated. In the case of a 3D sample with well defined separation surfaces the exponent is equal to -4 while it has lower values if the separation surface has fractal properties. In Fig. 1, bottom, GISAXS scans are plotted in log-log scale for Co submonolayer samples made with 5L (c) and 50L(d) of Xenon. The x axis is the momentum transfer. The scans have been normalized to the peak amplitude and the background signal from the substrate was substracted. The data show a power law dependence in log-log scale with exponent β that can vary between β=0.5 and β=2 in the various BLAG phases of the 50L Xenon sample, and β=1 for the 5L Xe sample.

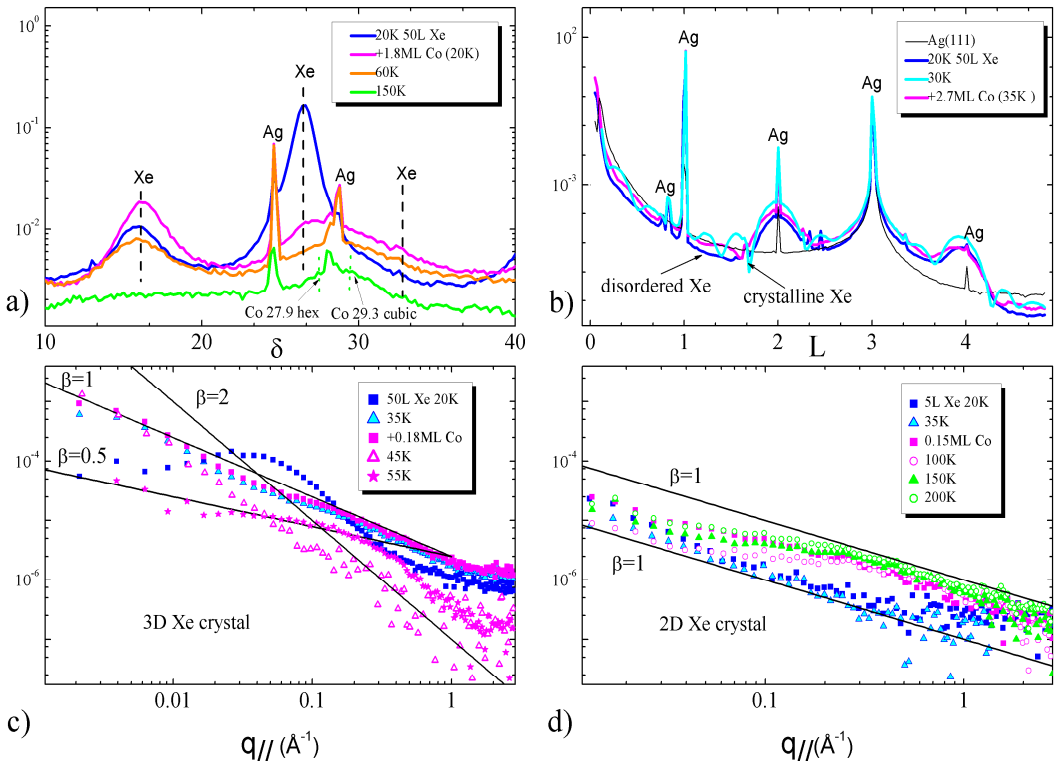

Figure 1: Top – δ-scans (a) and reflectivity (b) for 2-3ML of Co on 50L Xe on Ag(111); Bottom - GISAXS for ~ 0.2ML Co on 50L and 5L Xe ((c) and (d), respectively), together with power law curves for comparison.

Since the GISAXS intensity depends on the roughness of the surface, the scans taken during the different steps of the BLAG monitor changes in the morphology of the films. In the case of 50L Xenon layers (c) the GISAXS of pure Xe (turqouise symbols) and Co/Xe (magenta) measured at T=30K are similar, whereas for 5L Xe (d) they differ significantly. After the prominent effect of Co deposition on the GISAXS intensity though, no significant change is observed when annealing up to 200K (green). On the other hand, with Xenon desorption many changes occur in case of 50L: at 45K enhanced diffusion of Co on Xe gives a more disordered structure, while at even higher temperatures of 55K melting and then desorption of the Xenon multilayer seems to lead to a smoother interface. Contact between metal and substrate and progressive cluster diffusion induced by temperature leads to a negative GISAXS signal (not shown), which indicates that the ordering of the Co clusters on the Ag(111) is higher then of the clean Ag(111), maybe due to step decoration of the nanoclusters as observed also in STM images.

1 J. H. Weaver et al., Science **251** (1991) 1444