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Probing the Controlling Factors in Metal Epitaxy: In Situ Diffraction Study of the Growth of Co on Ru(0001)

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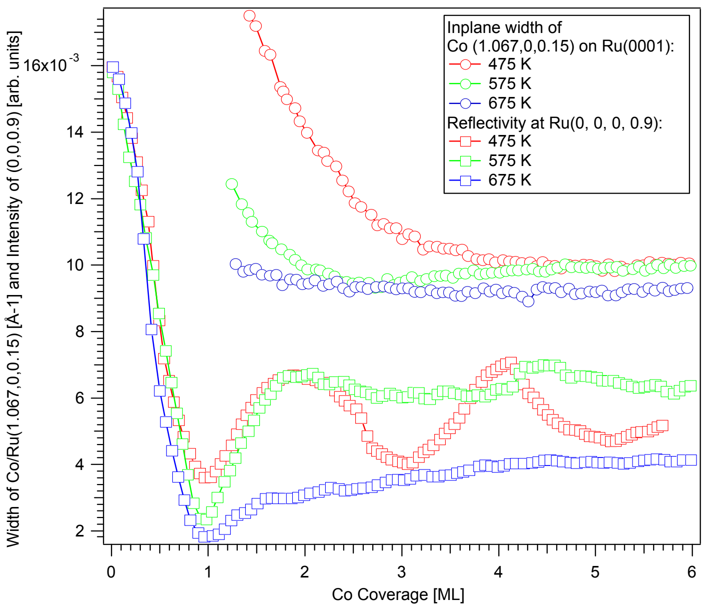
Introduction: The characterization of the structure, the morphology and the degree of order in thin metal films grown on metal substrates has been of increasing fundamental and technological interest, not only, but especially since the discovery of the GMR effect in metal multi-layer systems. The interest in the growth of thin metal films is in part based on a lack of quantitative knowledge about the factors which control their morphology and interfacial structure. This knowledge is crucial for their application as thin film magnetic systems for read heads in mass storage media or as bi-metallic catalysts. By monitoring the film growth with in situ x-ray diffraction techniques we found that control of the film growth by means of deposition rate and temperature is an effective tool to adjust growth conditions over wide range of structural order.

Methods: We have studied the growth mode of Co films on Ru(0001) and their dependence on temperature and deposition rate with surface x-ray diffraction techniques and under UHV conditions. The experimental setup allows in-situ measurements of the density, the unit-cell dimensions and the average strain distribution of the ad-layer film during Co deposition and for different substrate temperatures with very high resolution in reciprocal space and over macroscopic length scales on the sample.

Results: Our preliminary analysis of the diffraction data suggests that Co films grow preferably pseudomorphic with the Ru substrate for coverages up to 1 ML. Higher coverages cause an isotropic contraction of the Co overlayer leading to a significant strain relaxation with a lattice misfit reduction from initially 7.9% (pseudomorphic) to 1%. The resulting film is incommensurate with the hexagonal substrate and grows with a lateral periodicity of 4.16 nm x 4.16 nm. Its roughness and lateral order seems to improve significantly for elevated substrate temperatures up to 675 K. This is shown in the figure where the upper three plots demonstrate the dependence of the Co inplane peak width on temperature. We see that the average island diameter in the second layer drops nearly by a factor of 2 for a temperature decrease from 675 K to 475 K. For films thicker than 4 layers we observe a more uniform film growth which is less dependent on temperature but more sensitive to the deposition rate of Co which was typically set between 0.2 to 1 ML per 7 minutes and where lower rates lead to smoother interfaces. The increasing amplitude of the oscillations of the extended reflectivity at Ru(0,0,0.9) for temperatures below 675 K indicates that interlayer diffusion in the Co film seems to be proportionally dependent on temperature (lower three plots in the figure). This leads to larger lateral and smaller vertical island dimensions in the growing film for decreasing substrate temperatures.



The above trends are directly derived from the measurement of the extended reflectivity of the Co film on the Ru substrate at Qz = (0,0,0.9), the width and position of the Co island (1.069,0,0.15) reflection and the Co discommensuration wave vector at Q=(1,0.069,0.15). These positions in reciprocal space provide sufficient sensitivity to the vertical and lateral changes in the structure of the Co films, respectively, which provides a measure of their three dimensional degree of order and average morphology. It is the final goal of this study to deduct an average height and size distribution of the islands as a function of the growth temperature, the Co coverage and the deposition rate.

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