Abstract No. zajo0446

Formation and Control of Nanostructured Metallic Templates Through Oxygen Exposure

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Beamline(s): X22C

Introduction: Long ranged ordered nanostructured templates play a key role for the formation of regular arrays of nanoclusters with small size and height distribution. Examples for metallic systems are the well known herring bone reconstruction on Au(111) where regular Fe clusters form on top of it or the bilayer stripe phase of Cu on Ru(0001) with a spectacular whisker like growth mode of Cu(111) islands. These and similar systems offer the possibility to create new kinds of functional materials for magnets or catalysts where the properties are controlled by the dimensions of the template unit cells or the size of the created clusters. We have started to study the influence of oxygen exposure and substrate temperature on the template structure of the Cu stripe phase on Ru(0001) and found a new nanostructured O/Cu film which exhibits long range order.

Methods: We have examined the growth of O/Cu films on Ru(0001) and their dependence on temperature and on oxygen exposure with surface x-ray diffraction techniques under UHV conditions. This method allows in-situ measurements of the density, the degree of order, the unit-cell metrics and the average strain distribution of the ad-layer film during oxygen exposure and during temperature variation with very high resolution in reciprocal space and over macroscopic length scales on the substrate.

Results: After the Cu stripe phase was exposed to 5.5 L of oxygen at substrate temperatures of 375 K and simultaneously annealed to 595 K a diffraction pattern different from that of the uniaxial stripe phase was observed. It reveals the formation of a new strain driven biaxial superlattice in the Cu stripe phase which is reminiscent of the sulfur induced hexagonal pattern found by Hrbek et al. [1]. In-situ measurements with x-rays allowed us to probe the degree of order in the new phase as a function of oxygen exposure and temperature, leading us to the optimized growth conditions for its formation. The new nanostructured O/Cu bilayer showed a peak width of the fundamental (1.018, 0.018, 0.15) reflection of 0.0059 inverse Angstrom which implies a domain size of 1060 Angstrom. The corresponding symmetry of the diffraction pattern indicates a hexagonal system for the O/Cu-phase with unit cell dimensions of 7.155 nm x 7.155 nm. From the position of the primary superstructure reflections around the Ru(1,0,0.15) peak we determine an average strain relaxation of 69.2 percent in comparison to the oxygen free Cu stripe phase which brings the lattice misfit between substrate and ad-layer down to 1.1 percent. Reminiscent of the behavior of the S/Cu/Ru reconstruction, the quasi-hexagonal diffraction pattern of the O/Cu/Ru phase disappeared gradually at temperatures above 595 K and diffraction from the initial uniaxial Cu/Ru stripe phase returns proportionally. This process is reversible, cooling below 575 K returned the hexagonal pattern of the O/Cu phase. This fact suggests that the transitions between the surface structures are driven by strain caused by thermally induced small changes of the misfits of the elements involved. Exposure to higher doses of oxygen than 10 L and substrate temperatures below 575 K leads to diffraction from coexisting phases of Cu and O/Cu or to scattering from the one dimensional Cu stripe phase only.

Acknowledgements: We are grateful for the support of the X-ray Diffraction Group of the BNL Physics Department and for granting the beam time and the equipment for our experiments.

References:

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