E-beam PVD of various protective d-metal nanolayers on Mo; an AFM and ARXPS study on homogeniety, intermixture, and oxidation

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Mo/Si multilayers are used as artificial Bragg crystals to reflect and monochromate extreme ultraviolet radiation for lithography (EUVL). To improve the chemical resistance under the extremely high photon fluxes and hostile environment, a protective Ru "capping" layer is generally deposited on top of the terminating Si layer. In earlier work we observed that Ru diffuses through the Si, agglomerating at the Si-on-Mo interface, and applied a 2 nm thick Mo barrier layer between the Ru and Si to reduce this [1]. We now use angular resolved XPS (ARXPS), AES and AFM to characterize coverage, growth, roughness and oxidation of several transition metal layers ranging from monolayer to 4 nm thickness when grown onto the Mo layer by e-beam PVD to minimize implantation.

Au and Cu caps below an average thickness of 2 nm actually promote Mo oxidation, ARXPS revealing up to 70% oxidation of the subsurface Mo layer, while only 30% of the uncapped surface Mo layer was oxidized. Considering surface free energy and enthalpy of interface formation, closed Au and Cu growth but and minimal interface with Mo would be thermodynamically favored. AFM reveals surface agglomerations 0.1 and 0.05 µm in diameter and of 3.1 and 0.35 nm RMS roughness for the averagely 4 nm thick Au and Cu cap respectively, as depicted in Fig. 1 for Au. Co and Ni caps completely oxidize while even single monolayers manage to significantly reduce Mo oxidation, suggesting layer-by-layer growth. Pt, Pd, Rh and Ru take an intermediate position with Mo oxidation for caps thinner than 1.5 nm. The oxide in some cases appears nearer to the surface than the Mo^{6+}, suggesting sacrificial functionality. CO is directly adsorbed on all noble metal surfaces and apparent complete on top coke coverage builds up over time. The various observations are discussed with regard to kinetics.

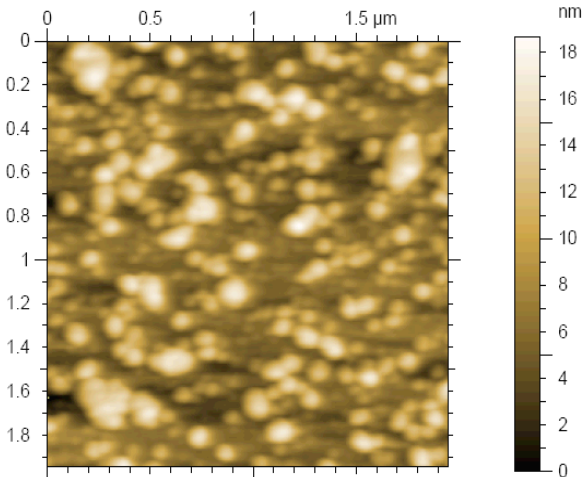

Fig. 1: AFM picture of a 4 nm thick Au capping layer on a 2 nm thick Mo layer shows a significant roughness with a lateral structure that suggests Volmer-Weber growth.

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