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Gold Cluster Growth on Polymer Thin Films during Sputter Deposition

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Fabricating nanocluster films with tailored morphology, their characterization and manipulation at the nanoscale are essential prerequisites for more efficient solar cells, biosensors, reflective or antireflective coatings, and heterogeneous catalyst. In order to tune the size-dependent optoelectronic properties, it is mandatory to monitor how the growth kinetics affect the metal film morphology and how it correlates to the optical properties during sputter deposition.
We employed a combination of in situ time-resolved Grazing Incidence Small Angle X-ray Scattering (GISAXS) with in situ UV/Vis Specular Reflectance Spectroscopy (SRS) during sputter deposition of gold on thin polystyrene films [1]. We monitored the evolution of the metallic layer morphology according to changes in the key scattering features by geometrical modeling [2] and correlate the nanostructural development to optical properties. This enables us to identify the different growth regimes including their specific thresholds with subnanometer resolution, which permits a better understanding of the growth kinetics of gold clusters and their self-organization into complex nanostructures on polymer substrates. During sputter deposition, a change in optical reflectivity of the pristine grey-blue polymer (polystyrene, PS) film occurred ranging from dark blue color due to the presence of isolated nanoclusters at the interface to bright red color from larger Au aggregates [3]. Furthermore, a surface diffusion coefficient according to the kinetic freezing model and interfacial energy of Au on PS at room temperature were calculated based on a real-time experiment. A recent study reports on the role of sputter deposition rate in tailoring metal layer morphologies on polymer thin films [4]. The deposition rate affects primarily the nucleation process and the adsorption-mediated growth, whereas rather small effects on diffusion-mediated growth processes are observed. Only at higher rates, initial particle densities are higher due to an increasing influence of random nucleation and an earlier onset of thin film percolation occurs.

[1] Schwartzkopf M and Roth SV; Nanomaterials, 6, 239 (2016).
[2] Schwartzkopf M et al.; Nanoscale, 5, 5053-5062 (2013).
[3] Schwartzkopf M et al.; ACS Appl. Mater. Interfaces, 7, 13547–13556 (2015).
[4] Schwartzkopf M et al.; ACS Appl. Mater. Interfaces, 9, 5629–5637 (2017).

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