In situ GISAXS investigation of gold sputter deposition onto colloidal polymer templates

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In the last few years, new applications for polymer-metal nanocomposites have emerged in the field of organic optics and electronics [1], or in the field of hybrid sensors [2]. Therefore, much effort has been put to better understand the growth kinetics of nanocomposites [3, 4].

We investigated in situ the growth of a sputter-deposited gold film (sputtering rate $R = 3.2 \text{ nm/min}$) on top of a pre-structured colloidal polymer template using grazing incidence small-angle X-ray scattering (GISAXS [5]). The underlying colloidal polymer template was deposited by using the novel technique of airbrush-spray coating, allowing for the installation of stripe-like trapezoidal pattern consisting of 3D hexagonally close-packed polystyrene (PS) colloids [6].

The GISAXS experiments were performed at the beamline BW4 [7] of the DORIS III storage ring at HASYLAB (DESY, Hamburg). The beam size was reduced to 20 $\mu$m x 60 $\mu$m (vertical x horizontal) by using an assembly of parabolic beryllium compound refractive lenses. We used a wavelength $\lambda = 0.138 \text{ nm}$ and a sample-to-detector distance $D_{SD} = 2.017 \text{ m}$. The GISAXS measurements were performed at two different incident angles $\alpha_i = 0.4^\circ$ and $0.7^\circ$ (Fig. 1), respectively below/above the critical angle of Gold $\alpha_c = 0.5^\circ$.

The side peaks clearly visible at $t = 0$ s (as indicated by the red stars in Fig. 1) reveal a typical lateral length scale of $(96 \pm 4)$ nm which corresponds to the nominal diameter of the PS colloids. Analysis of the GISAXS data shows a two-phase growth process with first ($0 \leq t \leq 120$ s) the nucleation and lateral growth of gold nanoclusters followed by the formation and vertical growth of a gold layer ($120 \leq t \leq 600$ s).

This original combination of deposition techniques (airbrush-spray coating / sputter deposition) opens a promising route to generate polymer-metal nanocomposites for applications such as plasmon waveguides and photonic crystals. Quantitative analysis of the 2D GISAXS pattern using IsGISAXS [8] is still underway.

References

Figure 1: GISAXS data ($\lambda = 0.138$ nm, $D_{SD} = 2.017$ m) obtained for $\alpha_i = 0.4^\circ$ (top) and $\alpha_i = 0.7^\circ$ (bottom). $t$ indicates the sputter deposition time. The horizontal red arrows highlight the diffuse scattering halo due to the nucleation and growth of the gold nanoclusters, the vertical white arrows point out the resonant diffuse scattering characteristic of the layer-by-layer growth.