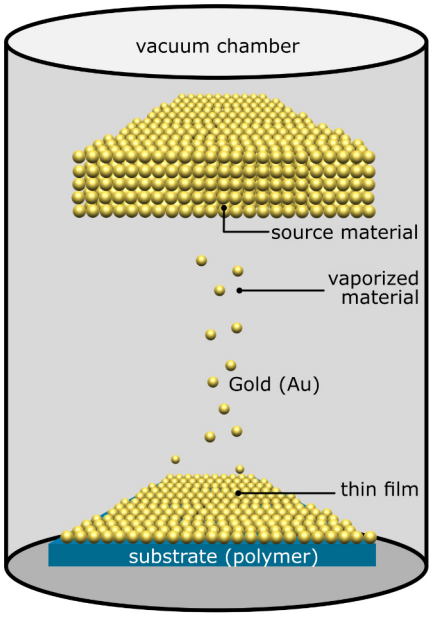
WATCHING A GOLD FILM GROW

Real-time observation of nanolayer formation at record speed



Nanomaterials composed of a polymer with an ultra-thin metal layer are used in a number of advanced technologies – such as organic LEDs in TVs or tablet screens, organic solar cells, sensors, or fuel cells. In many of these, they promise to improve cost-efficiency, which makes them particularly attractive for the industry. Thus, a lot of research is devoted to these metal-polymer hybrid materials and the optimization of their manufacturing. Ultra-thin metal layers, for example gold films, are created by sputter deposition: In essence, gold atoms are fired onto a substrate. This is done in a matter of a few seconds in industrial applications. As a consequence, if one desires to observe the gold atoms' behavior upon arrival at the substrate, one needs to monitor this process at very small spatial scales and with extremely high temporal resolution. This has now, for the first time, been achieved.

◂ Sputter deposition in nanolayer production

EXPERIMENTAL SETUP

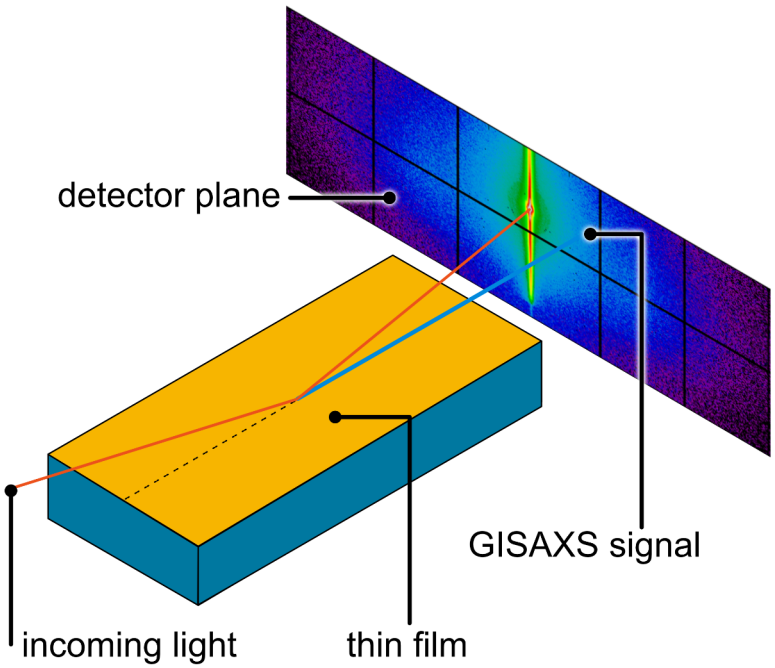
A team of researchers around Matthias Schwartzkopf from DESY (Germany) observed sputter deposition of gold atoms on a polystyrene substrate. They resolved the small spatial scales with X-rays, using a surface-sensitive geometry, so-called grazing-incidence small angle X-ray scattering (GISAXS), at the P03 beamline of PETRA III (DESY). The sub-millisecond resolution required by this experiment was achieved with a LAMBDA 750k detector, which allows image acquisition at rates of more than 23 kHz.

"**The LAMBDA detector, with its small pixel size and high frame rates, is an ideal detector platform for exploiting the high brilliance of modern synchrotron sources to gain real-time insights into rapid nanostructural processes"**, said Schwartzkopf. "This allowed us to examine the growth of an ultra-thin gold layer on polymeric substrate with a spatial resolution below a millionths of a millimeter and at 2,000 images per second, **a frame rate never before attained so far using surface-sensitive X-ray scattering at a synchrotron."**

Setup	PETRA III, DESY (Germany), P03 beamline
Camera	LAMBDA 750k Si detector
Resolution	786,432 pixels with 55 µm
Acquisition frequency	2 kHz
Photon energy	13 keV

RESULTS

With their experiments, Schwartzkopf and his co-workers gained insight into the gold nanolayer formation. They found that in the first few milliseconds, a fraction of the incoming gold atoms manages to penetrate the substrate material, while others begin to form vertical diatomic clusters. Subsurface enrichment with gold atoms already changes a material's thermodynamic behavior enough to "dope" polymer layers, which could be exploited in some applications. The authors also expressed confidence that this real-time observation of nanolayer formation could be used to study the effect of different deposition conditions, e.g., different substrate temperatures, and that this technique might also allow to control and optimize the manufacturing of metal-polymer hybrid materials.



GISAXS setup. In the detector plane, a typical scattering image is shown. It was summed over 100 single images 1 second after gold deposition started. The X-ray image was kindly provided by Matthias Schwartzkopf.

REFERENCE

- M. Schwartzkopf, S.-J. Wöhnert, V. Waclawek, N. Carstens, A. Rothkirch, J. Rubeck, M. Gensch, J. Drewes, O. Polonskyi, T. Strunskus, A. M. Hinz, S. J. Schaper, V. Körstgens, P. Müller-Buschbaum, F. Faupel and S. V. Roth (2021): Real-time insight into nanostructure evolution during the rapid formation of ultra-thin gold layers on polymers. Nanoscale Horizons 6, 132–138; https://doi.org/10.1039/D0NH00538J

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