In-situ grazing incidence X-ray scattering for thin film technology

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Thin film technology is a vast field. Fabricating nanoscale devices necessitates many process steps. They comprise many different deposition methods, ranging from fluid-based to physical vapor deposition (PVD), and are employed using layer-by-layer coating methods. The final device properties strongly depend on the precision – in terms of thickness, roughness, and nanostructural morphology – when depositing the different layers as well as their interaction at the interface of the multiple layers. Often, underlying layers are modified by and during subsequent deposition. Thus, it is crucial to observe the nanostructural growth of the coatings during the deposition. The kinetic processes involved are strongly in non-equilibrium. Here, grazing incidence X-ray scattering (GIXS) offers tremendous possibilities for observing in situ the development of coating using various thin film technologies [1,2].

I will give an overview of important applications of (GIXS) for elucidating growth mechanism on the nanoscale during the coating. PVD is widely used method for depositing tailored, dense metal layers, from nanogranular to thick coatings [3], depending on the device applications. Using GIXS, the full range of condensation, nucleation and growth of the metal layers is observed. GIXS reveals the different growth stages, their influence on the cluster shape and morphology [4]. In combination with optical spectroscopy, the nanostructure of the layers is related to their electronic properties [5]. Recently, industrial relevant sputter rates were employed, and the influence of them elucidated [6]. Besides the high temporal resolution and with ongoing device miniaturization, curved and line-type structures such as coated fibres come into focus. GIXS combined with nanobeams offers unique opportunities for investigating the coating morphology on these microscopic structures [7].

The second route is dedicated to the observation of spray coating. Spray coating presents a rapid, scalable, and layer-by-layer (LbL) capable coating method, vastly employed in coating science. With the quest for sustainability, the use of cellulose-based materials is crucial. These biomaterials offer highest strength by translating their nanoscale properties to macroscopic fibres [8]. Hence, they may serve in future for templates in flexible electronics. In a first step, we therefore investigated the LbL deposition of cellulose nanofibrils (CNF) by spray coating and combining with grazing incidence wide-angle and small-angle X-ray scattering (GIWAXS/GISAXS) [9]. Using modified CNF, layers with ultralow roughness and tailored wettability are fabricated. Here, the use of complementary neutron methods is highly useful [10]. To finalize, I will give an outlook on applications of GIXS for investigating 3D printing in flexible electronics [11].

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