Invited Lecture

In-situ nanoscale characterization of strains and microstructure

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Thin films possess complex gradients of residual strains and stresses, which vary laterally and also across film thickness. These originate (i) from self-organized film growth, (ii) from intentionally varying deposition conditions and/or (iii) from inhomogeneous thermal and/or mechanical loads applied during service. In order to reveal those gradients and subsequently optimize functional properties of thin films, it is necessary to apply nanoscale characterization approaches.

Cross-sectional synchrotron X-ray nanodiffraction (CSnanoXRD) [1] using monochromatic X-ray beams with a diameter down to ~30 nm provides representative depth-resolved data on the evolution of phases, crystallographic texture, grain morphology and strains/stresses across thin film cross-sections. The aim of this contribution is to discuss methodological and instrumental aspects of the approach as well as to present recent achievements from experiments at the beamlines ID13 of ESRF. By the examples of hard nitride, diamond and metallic thin films, it will be demonstrated that the new approach can serve as an effective tool to characterize the inhomogeneous properties of as-deposited and in-situ mechanically-loaded films. The observed gradients can be correlated with the varying film deposition conditions, providing an opportunity to optimize the time-dependent synthesis process and perform knowledge-based design of the nanocrystalline thin films. Finally, an outlook, especially on in-situ experiments as well as an analysis of complex depth gradients of structure-property relationships in nanocrystalline thin films, performed with even smaller X-ray beams, will be discussed.

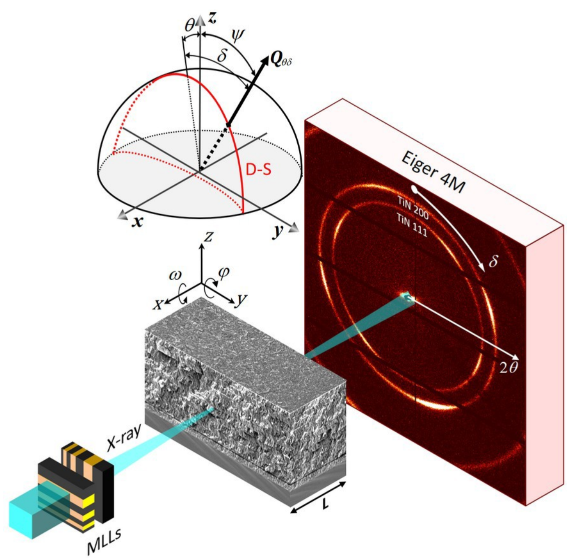

Figure 1. A schematic setup of a CSnanoXRD experiment at the ID13 bemaline. X-ray beam with a diameter of 30 nm is focused using two crossed multilayer Laue lenses. The sample is scanned along *y* and *z* axes and the diffracted signal is collected using a 2D detector.

[1] Keckes, J., Daniel, R., Todt, J., Zalesak, J., Sartory, B., Braun, S., Gluch, J., Rosenthal, M., Burghammer, M., Mitterer, C., Niese, S; Kubec, A. (2018) *Acta Mater.* **144**, 862.