Compact PLD Sample Environments for In-Situ X-Ray Studies of Thin-Film Growth at Synchrotron Beamlines

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In-situ studies of thin-film growth are important for understanding how interfaces, strain, defects and functional properties appear during deposition. For X-ray methods this is especially attractive, because diffraction, scattering and photoemission can follow the structure and electronic state of a film before the sample is removed from the growth environment. At the same time, this creates a practical problem: the deposition system must fit into the beamline geometry, provide optical and X-ray access, work under UHV or controlled gas atmosphere, and keep the sample position stable enough for precise X-ray measurements.

In this contribution we present compact pulsed laser deposition (cPLD) systems developed as sample environments for synchrotron beamlines. The main advantage of PLD for this task is that the laser is located outside the vacuum chamber. Therefore, the chamber can be made small, light and beamline-adapted, while still keeping the flexibility of PLD for oxides, metals and multilayer structures.

A representative example is the portable cPLD chamber used at the P23 beamline of PETRA III for in-situ X-ray diffraction studies of oxide thin-film growth. The system had a total weight of about 12 kg, allowed growth at temperatures up to 800 °C in oxygen atmosphere, and was compatible with laser wavelengths of 266 and 532 nm. During BaTiO3 deposition on different substrates, diffraction curves of the BaTiO3 (001) reflection were recorded after defined numbers of laser pulses. This made it possible to follow the evolution of the film during growth and to correlate thickness, strain state, substrate material, temperature and cooling conditions. In a related NiO study, growth oscillations and post-growth analysis were used to identify defect formation and tune the properties of the film.

We also discuss the extension of the same approach to in-vacuo PLD–HAXPES workflows at PETRA III, where thin films grown by PLD can be transferred and studied without exposure to air. Such experiments are especially useful for oxide/metal interfaces and magnetic heterostructures, where the photoelectron spectra depend on magnetization, X-ray polarization and emission geometry.

The examples show that compact PLD can work not only as a preparation tool, but as a real X-ray sample environment. It enables direct feedback between synthesis and characterization, reduces uncertainty caused by ex-situ handling, and opens a practical route to operando studies of thin-film formation at synchrotron facilities.

Fig. 1. Compact PLD sample environment for in-situ X-ray studies at PETRA III.The system enables pulsed-laser deposition directly in the synchrotron beamline with in-situ X-ray diffraction monitoring