Internship Proposal (M2)

Fast Atom Diffraction in high-pressure vacuum: application to real-time characterization of the growth of ultra-thin layers by HiPIMS

In the form of ultrathin layers, materials can show interesting properties that are different from those of the bulk. Beyond the potential applications enabled by these properties, describing and understanding the mechanisms of formation of these ultrathin layers and their impact on the properties (structural, electronic, optical, etc.) represents a fundamental challenge. To achieve this goal, it is essential to be able to monitor the growth process in real time and to describe its key parameters (growth rate and mode, morphology and crystalline structure, strain level) with high sensitivity. For vacuum deposition, high-energy electron diffraction at grazing incidence (RHEED) meets this condition quite well; RHEED is widely used to monitor molecular beam epitaxy (MBE) and its use has been extended to Pulsed Laser Deposition (PLD). Nonetheless, because of the electromagnetic fields present in the deposition zone, RHEED is incompatible with deposition by magnetron plasma sputtering. However, this mode of deposition has become a worldwide technology for producing a wide variety of nanostructures in thin layers, from metals to oxides and 2D materials.

We have developed a new surface analysis technique exploiting the quantum scattering of helium atoms with energy around the keV. Called GIFAD (Grazing Incidence Fast Atom Diffraction), this technique is an advantageous alternative to RHEED since it offers much better surface sensitivity and provides richer information on both crystallographic structure and growth dynamics. In a new configuration, GIFAD can now operate at pressures up to 10^{-2} mbar, allowing its use for deposition modes operating at “high pressure” (reactive PLD, CVD, magnetron sputtering). The preliminary results obtained in a HiPIMS (High Power Impulse Magnetron Sputtering, a variant of magnetron plasma sputtering) deposition chamber are encouraging. The objective of the internship is to progress on real-time measurements applied to the growth of thin layers of oxides (TiO_2, VO_2) by reactive deposition (in the presence of oxygen) but also of 2D materials (transition metal dichalcogenides). In particular, we will focus on resolving the early stage of the growth dynamics at the interface and the influence of the deposition parameters (pulse power and duration, oxygen pressure, acceleration voltage of the sputtered ions, etc.). Since HiPIMS is particularly favourable for epitaxial growth, the real-time characterization enabled by GIFAD should ease the optimization of the deposition parameters and achieve thin layers with optimal structural properties.

This project is part of a collaboration between the ISMO and the LPGP (Laboratoire de Physique des Gaz et des Plasmas, Paris-Saclay University) and benefits from the support of CNRS through the Prematuration program. **This internship may be extended to a PhD project (EDOM doctoral school)**.

Location: Institut des Sciences Moléculaires d’Orsay (ISMO), Bât. 520, Université Paris-Saclay, Orsay
Contact : Hocine Khemliche, hocine.khemliche@universite-paris-saclay.fr; 33 (0)1 69 15 75 49 (or 44 79)

References:

- “Epitaxial growth of Cu(001) thin films onto Si(001) using a single-step HiPIMS process”; https://doi.org/10.1038/s41598-017-01755-8
- https://www.cnrs.fr/cnrsinnovation-lalettre/actus.php?numero=220
- “Dynamic grazing incidence fast atom diffraction during molecular beam epitaxial growth of GaAs”; https://doi.org/10.1063/1.4890121
- "Grazing incidence fast atom diffraction in high-pressure conditions"; https://doi.org/10.1016/j.surfin.2023.102754
- Patent “Dispositif d'analyse de surface par diffraction d'atomes rapides dans un environnement haute pression”, EP4099005A1, 2022