PhD thesis

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

In the form of thin layers, materials sometimes show unique properties, different from those of the bulk material. Beyond the potential applications enabled by these properties, describing and understanding the mechanisms of formation of these thin layers and their impact on the properties (structural, electronic, optical, etc.) represents a fundamental challenge. To this end, 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 great 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 technique of choice for the production of a wide variety of nanostructures in thin layers, from metals to oxides through 2D materials.

We have developed at ISMO 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 the crystallographic structure. In a brand new configuration, protected by a patent, GIFAD can operate at pressures of 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) deposition chamber, a variant of magnetron plasma sputtering, are encouraging. In particular, we know how to limit the impact of particles from the high-power plasma pulses on the GIFAD detector. The objective of the thesis project is to progress on real-time measurements applied to the growth of thin layers of oxides (TiO2, VO2) by reactive deposition (in the presence of oxygen) but also of 2D materials (transition metal chalcogenides). In particular, we will focus on resolving the very first stage of growth at the interface and the influence of the deposition parameters (power and duration of the pulses, oxygen pressure, acceleration voltage of the sputtered ions, etc. .). Since the HiPIMS mode is particularly favourable for epitaxial growth, the real-time characterization enabled by GIFAD should ease the optimization of the deposition parameters in order to produce thin layers with optimal properties.

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