Insight into pulsed laser deposition of selected oxynitride system. Oxidation control via plasma diagnostic tools

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In recent years, there has been a significant surge in advancements in thin film technology aimed at fostering clean and renewable energy sources. However, a critical challenge that persists is the upscaling of manufacturing processes, thus a paradigm shift in the industrialization of certain technologies occurred focused on the automation of the process. Among the myriad of technological solutions, Pulsed Laser Deposition (PLD) stands out as an exceptionally versatile tool for producing a wide range of nanoscale materials with precisely controllable properties.

Our research group has demonstrated in recent years that in-situ monitoring of the PLD process is crucial for establishing correlations between plasma behaviour and thin film characteristics, thus paving the way for process automation. In this study, we apply this approach to gain insights into the formation of oxynitride films. Beginning with a bottom-up approach, we characterize the deposition process of selected oxides and oxynitrides (such as TiOxNy, ZrOxNy, and HfOxNy) with the objective of elucidating plasma-thin film relationships to facilitate the upscaling of PLD technology.

Our investigations employed angle and time-resolved Langmuir probe techniques coupled with real-time optical emission spectroscopy to scrutinize the deposition process. We identified distinct signatures in the charge particle density distribution for gas-phase oxidation processes involving metallic species. Time-resolved analysis unveiled the intricate dynamics of a two-temperature plasma with distinctive angular structuring. To account for the peculiarities of PLD, both on-axis and off-axis deposition geometries were employed to examine the influence of charge kinetic energy on defect and oxynitride phase formation. Subsequently, the deposited films underwent comprehensive characterization using Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD), X-ray Photoelectron Spectroscopy (XPS), and electrical measurements. Finally, we established correlations between plasma properties during deposition and selected physical properties of the film, thereby identifying optimal conditions for the development of tailored oxynitride coatings

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