9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Residual Stress and Related Properties of TiO_2/TiN/TiC Thin Films Deposited by Ion Energy Modulated ALIS and Magnetron Sputtering Hybrid Process

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To achieve tunable microstructures and effective residual stress management in functional ceramic thin films, this study investigates a hybrid plasma-enhanced deposition method that integrates an Anode Layer Ion Source (ALIS) with magnetron sputtering for the deposition of TiO_2/ TiN/ TiC thin films [1]. In this dual-source configuration, magnetron sputtering provides material deposition, while the ALIS is engineered with different electrode and magnetic field designs to produce two distinct ion energy regimes, namely high-voltage ALIS and low-voltage ALIS [2]. Reactive gases are introduced, and the ion energy is precisely adjusted [3], thereby simultaneously suppressing film re-sputtering and promoting film densification processes [4], which significantly enhance the optical and mechanical properties, structural integrity, and interfacial adhesion of these thin films [5]. By finely tuning the ALIS ion bombardment conditions and controlling the compound film formation rate via magnetron sputtering technique, it is possible to effectively regulate the residual stress and the ceramic transformation process of the thin films, while maintaining excellent optical and mechanical properties of the thin films. To investigate the influence of ion energy on film morphology and optical characteristics, Ti-based ceramic thin films were deposited onto optical-grade B270 and H-K9L glass substrates. The experiments systematically varied the magnetron sputtering parameters, ALIS ion energy, and reactive gas compositions ($Ar/O_2/N_2/C_2H_2$). In terms of measuring thin film properties, we use a Twyman Green interferometer to measure residual stress and a Linnik interferometer to analyze surface roughness. These results indicate that ion energy critically affects grain packing density, porosity formation, and residual stress behavior [6]. This ion-assisted hybrid co-deposition technique demonstrates strong potential for fabricating high-density ceramic thin films with controllable residual stress and surface morphology. It is particularly well-suited for applications requiring exceptional mechanical reliability and stress tolerance, such as optical coatings, protective surface layers, and advanced microelectronic structures [7].

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