

## Seminar

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### From Hardness to Photonics: Self-Organized Nanostructures in Transition-Metal Nitride Thin Films

#### Abstract

At the Thin Film Physics Division of Linköping University, we investigate immiscible transition-metal nitride systems as model platforms for designing multifunctional nanostructured materials. By combining epitaxial thin-film growth with advanced microscopy, diffraction, and theoretical modeling, we explore how thermodynamic immiscibility and kinetic limitations drive self-organization into nanoscale architectures.

A central focus is understanding decomposition pathways and nanostructure formation in metastable nitride alloys during high-mobility growth. Systems such as Zr–Al–N, Zr–Si–N, and Hf–Al–N demonstrate a rich variety of self-assembled morphologies including nanolabyrinthine lamellae, columnar nanocomposites, and three-dimensional checkerboard superstructures with periodicities down to the sub-nanometer scale. These structures arise from surface-diffusion-mediated segregation, spinodal decomposition, and defect-driven ordering processes.

The resulting nanoscale architectures strongly influence mechanical behavior, enabling hardness values exceeding 35–40 GPa through mechanisms such as Koehler hardening, coherent interface strengthening, and dislocation pinning by superstructure strain fields. Remarkably, hyper-overstoichiometric HfN-based films can exhibit an unusual combination of high hardness and metallic-like ductility associated with vacancy–interstitial superstructures.

Beyond mechanical performance, these nanostructured nitrides exhibit tunable optical properties spanning metallic to dielectric regimes. Spectroscopic ellipsometry reveals composition-dependent refractive indices and extinction coefficients that enable the design of antireflection coatings, high-reflectivity multilayers, and chiral sculptured thin films with circular Bragg resonances in the visible range.

During my visiting professorship at Institut Jean Lamour in Nancy, this presentation aims to stimulate discussion and potentially initiate fruitful collaborations in the exploration of nanostructured nitride thin films during my extended research stay in the coming summer.

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