## PhD thesis

# NANOengineering INTerfaces and adhesion in INTerface-dominated materials (Nano-INT²)

**Research Unit:** Laboratoire des Sciences des Procédés et des Matériaux (LSPM), **axis:** Procédés PlasmA, Nanostructures et films Minces (PPANAM), **research team:** Mécanique des Films Minces Fonctionnels (2MF)
**Supervisors: Matteo Ghidelli ([matteo.ghidelli@lspm.cnrs.fr](mailto:matteo.ghidelli@lspm.cnrs.fr)) & Martin Robin ([martin.robin@lspm.cnrs.fr](mailto:martin.robin@lspm.cnrs.fr))**
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**Short description of the PhD project: Nanolaminated (NL) metallic materials** constituted by layers of different compositions/atomic structures and ultrahigh density of nanointerfaces, are currently emerging as novel high-performance materials showing excellent strength/ductility balance, high hardness and thermal stability. **The large density of interfaces** (layers thicknesses typically < 100 nm) and **the high interface adhesion/strength**, have been proved **to arrest crack propagation**, while improving hardness/yield strength by blocking dislocations/shear bands or activating plasticity by triggering mechanical size effects. Moreover, contrary to monolithic counterparts, the **mechanical properties of NLs can be easily tailored by varying interface density/type**, enabling to easily match with specific application requirements. However, **the relationship between the NL structure and the mechanical behavior** is still **an open research area**, especially focusing on the effect of interface density and interlayer strength/adhesion.

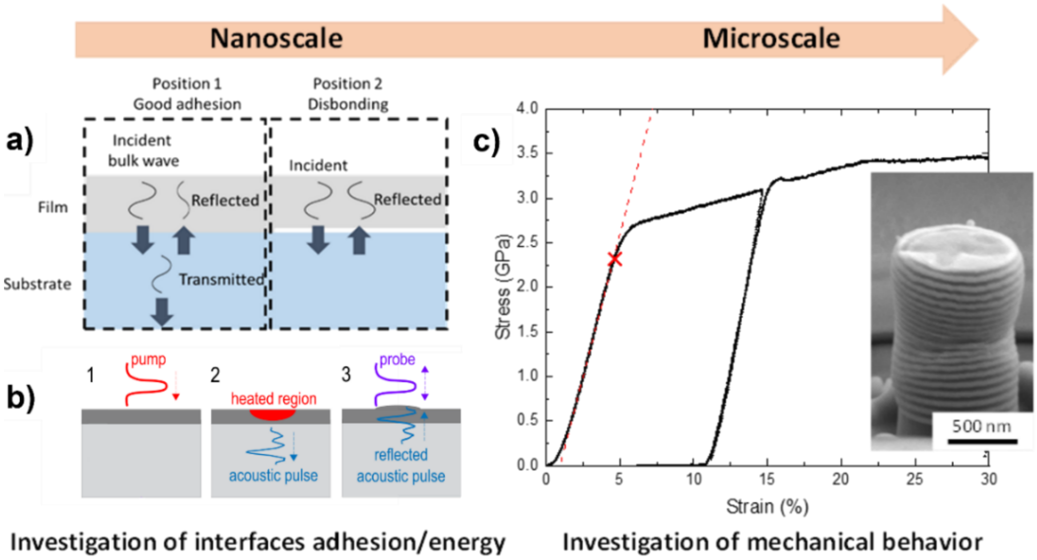


*Fig. 1 – Schematic of the research concepts within the Nano-INT² project. (a) Nanoscale characterization of interfaces adhesion by optoacoustic-techniques. (b) Principle of optoacoustics. (c) Microscale characterization of Al/CoCrCuFeNi NLs by in situ SEM micropillar compression.*

Within Nano-INT², we propose to in-depth investigate this topic focusing on model metallic NL structures and exploiting **an original approach which combine the acoustic investigation of interfaces adhesion/strength (optoacoustic techniques, Fig. 1a, b) with *in* and *ex situ* Scanning Electron Microscopy (SEM) mechanical testing (nanoindentation and micropillar compression)** aimed to assess the elasto-plastic properties and the deformation behavior (Fig. 1c). Finally, direct nanoscale observation of interfaces with high resolution transmission electron microscopy techniques will be carried out c**ollaborating with the group of Prof. Hosni Idrissi** (UCLouvain, Belgium). The samples will be fabricated by magnetron sputtering progressively increasing the density of interfaces, by decreasing the thickness of the layers, triggering interface-induced mechanical size effects, while investing adhesion and the mechanical properties. Different combinations of **model NL materials** will be studied with expected significant contrast of adhesion, mechanical properties and deformation behavior. We will focus on advanced metallic NLs with amorphous/amorphous and amorphous/crystalline interfaces, including amorphous (ZrCu) and crystalline (high/medium entropy alloys, such as FCC CoCuCrFeNi, or BCC TiZrHf) [1-3]. Post-thermal annealing treatments, will be investigated aimed to further tailor the interfaces, favoring layers intermixing and investigating the effect on adhesion and mechanical behavior.

Overall, **we plan to achieve a holistic understating of interface effect on mechanical properties of NL metallic materials**, paving the way to the synthesis of novel interface-dominated materials with key industry impact.

**References:** **[1]** A. Brognara *et al.*, "Tailoring mechanical properties and shear band propagation in ZrCu metallic glass nanolaminates through chemical heterogeneities and interface density", *Small Structures*, 2024. **[2]** F. Bignoli *et al.*, "Novel class of crystal/glass ultrafine nanolaminates with large and tunable mechanical properties", *ACS Appl. Mater. Interfaces*, 2024. **[3]** Y. Zhang *et al.*, "Strong interfaces: the key to high strength in nano metallic laminates", *Acta Mater.*, 2024. **[4]** M. Lee *et al.*, "Self-sealing complex oxide resonators", *Nano Lett.*, 2022. **[5]** M. Robin, *et al.*, "Influence of the laser source position on the generation of Rayleigh modes in a layer-substrate structure varying degrees of adhesion", *Ultrasonics*, 2020.