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Institut d'Electronique, de Microélectronique et de Nanotechnologie
UMR CNRS 8520

Master or Engineer internship 2025-2026

Proposed by : MEMS Bioinspired Team: Prof. Cattan-GrondeL-Ghenna Phone number : 03 27 51 12 43

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Title : **Characterization and Modeling of Monolayer and Multilayer Ionic Polymer-Based Materials**

Context: Ionic polymer materials, in the form of monolayer or multilayer thin films, exhibit promising mechanical and electroactive properties for applications in micro-actuators, soft sensors, and bio-inspired devices. A detailed understanding of their mechanical behavior, especially in the presence of clamped boundary conditions and electrical actuation, is essential for optimizing their performance. This internship is part of a broader research project aimed at characterizing, modeling, and predicting the mechanical behavior of such materials, with a focus on the Saint-Venant principle, electro-chemo-mechanical coupling, and multilayer effects.

Part 1 – Experimental Characterization

The first part of the internship will involve the mechanical characterization of monolayer (e.g., polyimide) and multilayer (e.g., ionic trilayer) polymer films using several complementary techniques:

- Static stiffness measurements using a force sensor under imposed deflection (cantilever beam configuration)
- Dynamic release experiments to extract the equivalent stiffness and highlight the effect of boundary conditions or material gradients
- Additional measurements: Young's modulus, viscoelasticity, and mass density using mechanical and/or indirect methods

Key objectives include: Evaluating the reproducibility of measurements. Comparing homogeneous monolayers (metallic or polymer) and heterogeneous multilayers. Investigating the minimal distance required from the clamping zone for reliable measurements, in relation to the Saint-Venant principle

Part 2 – Analytical and Numerical Modeling

The second phase will focus on developing mechanical models of these materials under two main regimes:

1. Small-displacement regime under mechanical loading (force-imposed deformation), corresponding to the passive characterization phase
2. Large-displacement regime under electrical actuation, modeled as an **internal electro-chemo-mechanical moment** inducing bending

Tools and approaches will include:

- Analytical modeling (multilayer beams, shear effects, imperfect interfaces)
- Numerical simulation (2D or 3D finite element methods, with adapted constitutive laws)
- Analysis of clamping effects propagation in multilayer structures
- Comparison with experimental results

Skills to be developed

- Solid mechanics, structural behavior (beams, plates)
- Experimental characterization techniques
- Analytical modeling (elasticity, Saint-Venant principle, multilayers)
- Introduction to FEM simulation (e.g., COMSOL, ANSYS, or similar)
- Scientific writing, critical data analysis

Hosting Lab: The internship will take place at the **IEMN Laboratory – Valenciennes site**, within a research team that combines experimental and theoretical approaches in soft materials mechanics and active systems. The student will interact regularly with experts in ionic polymer actuators and multilayer mechanics.

Duration

5 to 6 months (depending on the student's academic requirements), preferred start: February or March 2026

Candidate Profile

Master's student or final-year engineering student with a background in mechanics, materials science, or applied physics. Motivation for both experimental work and modeling is essential.