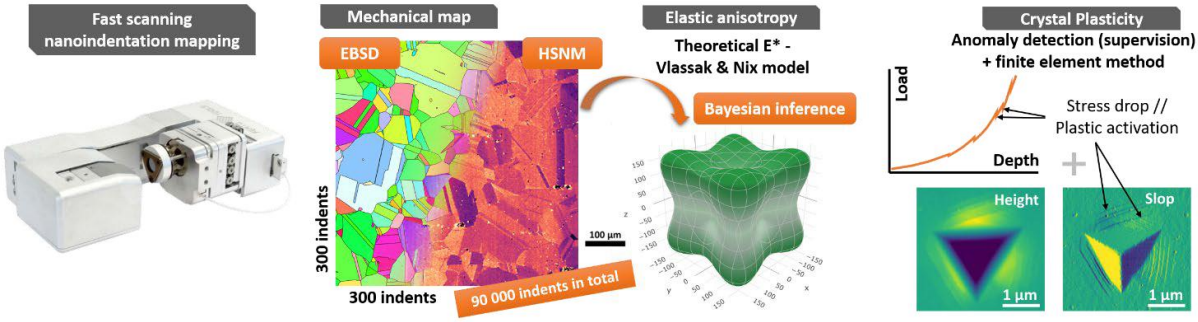
PhD Position: Mechanical correlative microscopy by nanoindentation for high-throughput microstructural characterizations

OVERVIEW:
We are seeking a highly motivated PhD candidate to join our research team working on advanced characterization approaches for fast screening of elastic and plastic properties of metallic materials at the microscale.

KEYWORDS: nanoindentation, SEM/EBSD, slip bands, grain boundaries, micromechanics, statistical analysis



RESEARCH FOCUS:
High speed nanoindentation mapping (HSNM) is becoming very effective in evaluating the mechanical properties of materials from correlative measurements, such as lattice orientation by EBSD or local chemical composition by EDX [1]. For instance, an original protocol based on Bayesian inference was recently co-developed by LEM3 and ICA to determine the single-crystal elastic constants of cubic crystals from HSNM and EBSD correlative measurements [2]. Such a mechanical correlative microscopy approach was also used to study the effect of oxygen content on titanium's elastic properties [3,4]. The present PhD aims to fully exploit the potential of the HSNM technique on materials with gradients of microstructures and properties. The objective is twofold: first, provide fruitful data to calibrate physics-based crystal plasticity models and inform them with key parameters (e.g., variation of single-crystal elastic constants and critical resolved shear stresses with microstructural features, interfaces strengths), secondly, gain a better understanding of the mechanisms leading to strain localization which has a determinative role in influencing the suitability of a given material for an intended structural application. To conduct this study, a nickel-based superalloy (Inconel 718) will be used as a model material because of its broad industrial applicability and its remarkable metallurgical modularity, enabling the elaboration of specimens with gradients of microstructural states (from solid solution to precipitation hardened) directly influencing its strain localization. The PhD research will notably involve:

- Preparation of INCONEL 718 specimens having a gradient of precipitation along the tensile direction (1), chemically-graded specimens for controlled gradients in Nb and/or Al content (2), and pre-deformed samples (3).
- Application of high-speed nanoindentation maps combined with EBSD and/or EDX measurements that allows for data merging/correlative measurements to subsequently extract mechanical properties.
- Statistical analysis of slip bands around indents and stress drops occurring during nanoindentation tests [5] with respect to lattice orientation, chemical composition, metallurgical state, and distance to grain or twin boundary.
- Study of the strength of grains and twin boundaries and the constraint of plasticity by interfaces from the deviation of classical indentation size effect (ISE) [6] obtained in nanoindentation tests carried out in continuous stiffness measurement (CSM) mode close to interfaces.

REQUIRED SKILLS

- Master's degree in Materials Science, Mechanical Engineering or a related field
- Knowledge of crystal defects (grain boundaries, dislocations, slip bands, precipitates, etc.)
- Experience in materials characterization techniques
- Programming skills (Python, MATLAB, C++, or similar)
- Familiarity with machine learning approaches would be a plus
- Good written and verbal communication skills in English
- Ability to work independently and as part of a multidisciplinary team

WORK CONTEXT:

This is a fully funded PhD position for 3 years (2300 € (gross) per month) supported by the PEPR DIADEM program. The PhD candidate will be recruited in the framework of the AMMETIS (AI-assisted Simulations of Microstructure driven Mechanical properties from high Throughput and multiscale analysIS) project which is based on an effective collaboration between LEM3, ICA, PIMM and CEA. The PhD candidate will be mainly located at LEM3 in Metz, while making long stays at ICA in Toulouse at the beginning of the thesis to perform experimental campaigns. He will be involved in the AMMETIS'team composed of experienced researchers from CNRS, UL, Arts et métiers, IMT and CEA, as well as several PhD students and post-doctoral researchers, working on high-throughput material characterization and micromechanical modelling, both assisted by AI. The PhD candidate will have access to state-of-the-art research facilities and computational resources. He will be offered the opportunity to participate in in international conferences, workshops, and training events.

SUPERVISORY TEAM:

Thiebaud RICHETON, Directeur de recherche au CNRS, *thiebaud.richeton@univ-lorraine.fr*
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APPLICATION:

Please apply online via the CNRS job portal at the address below:
https://emploi.cnrs.fr/Offres/Doctorant/UMR7239-THIRIC-003/Default.aspx

REFERENCES:

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