Laboratoire des Sciences des Procédés et des Matériaux (LSPM, CNRS) - UPR 3407

Micro-and nanostructured materials lab.

PhD position

Towards new multielemental amorphous thin films with enhanced mechanical properties and thermal stability

Supervision: Prof. Damien Faurie, Dr. Matteo Ghidelli (Laboratoire des Sciences des Procédés et des Matériaux, LSPM-CNRS, Université Sorbonne Paris Nord, USPN, France).
Co-supervision: Prof. Andrea Li Bassi (Laboratorio di Materiali Micro- e Nanostrutturati, NanoLab, Politecnico di Milano, POLIMI, Italy).
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Keywords: thin films; metallic glasses; mechanical properties; thermal stability; magnetron sputtering; pulsed laser deposition.

A **fully funded 3-years joint PhD** is available supported by the prestigious VINCI program (Cap. III) of the **French-Italian University** (https://www.universite-franco-italienne.org/). At the end of the PhD, the student will be entitled of a **double PhD degree** issued by the **University Sorbonne Paris Nord** (USPN, France, main institution) & the **Politecnico di Milano** (POLIMI, Italy, partner institution). The student is supposed to spend **at least 1 year** within the partner institution (POLIMI).

Short description of the PhD project

Thin film metallic glasses (TFMGs) are object of increasing scientific interest due to their excellent mechanical properties, e.g. yield strength close to the theoretical limit (>3 GPa) and large elastic deformation (~5%) [1,2]. Moreover, their disordered atomic structure is at the origin of unique functional properties including corrosion resistance and biocompatibility [1]. However, the research on the synthesis and characterization of TFMGs is in a preliminary phase, preferring investigations on bulk counterparts [1]. In this context, this project focuses on synthesis of metallic films with disordered structure at the nanoscale obtained through vapor phase deposition techniques and on the investigation of relationship between atomic structure–mechanical properties–thermal stability.

In the synthesis phase, we aim of extending the amorphization range from simple elemental metals to binary (Zr_xCu_{100-x}), ternary alloys (ZrCuAl/Pd) and up to 5 elements: amorphous high entropy alloys. Two different deposition techniques will be used: magnetron sputtering (@LSPM) and pulsed laser deposition (PLD, @NanoLab). This will enable to investigate the atomic structure and properties as a function of the synthesis technique, while the PLD will enable to produce new amorphous alloys by exploiting the rapid rate of cooling of the ablated species [3]. The mechanical characterization will focus on optoacoustic techniques [4] combined with nanoindentation and *in-situ* SEM/AFM tensile tests for films deposited on polymer substrates [5]. The study of the effect of structure/composition/deposition technique on mechanical properties will shed light on the evolution of elastic constants, hardness,

plastic deformation, while observing various deformation mechanisms on a microscopic scale, still unknown to date. The investigation on thermal stability, by *in-situ* and *ex-situ* annealing treatments, will shed light on devitrification phenomena and on the formation of a crystalline phase.

Finally, the comprehension of these properties will enable to develop new TFMGs with optimized architectures including nanoporous, multilayer and nanocomposites (Figure 1) with expected high performance and capable to resist in aggressive environments or subjected to intense thermo-mechanical stresses. This will extend their use in several applications fields in key industry sectors involving energy, aerospace and biomedics [3].

[1] M. Ashby *et al.* Scripta Mater., 54, 321, 2006.
[2] M. Ghidelli *et al.,* Acta Materialia 131, 246-259, 2017.
[3] S. Lee *et al.,* Nano Lett., 20, 7, 4872–4881, 2020.
[4] M. Apreutesei *et al.,* J. Alloys Compd. 707, 126, 2017.
[5] S. Merabtine *et al.*, Nano Lett. 18 (5), 3199-3202, 2018.

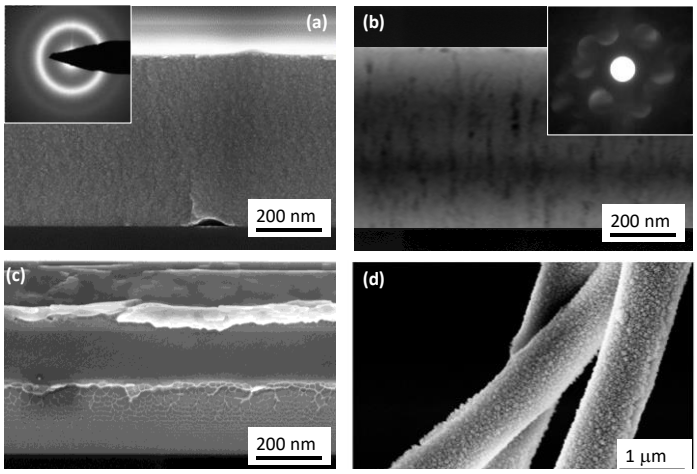

Figure 1: (a-c) New TFMGs exhibiting different morphologies: nanoporous (a), nanocomposite (b) and multilayers (c). (d) Deposition of nanoporous TFMGs on polymeric fibers for thermotherapy heat patches [3].

PhD tasks

- TFMG deposition by magnetron sputtering and pulsed laser deposition with different composition and thickness;
- Study of the structural/mechanical properties and thermal stability;
- Design of engineered TFMGs with enhanced mechanical properties/thermal stability and characterization.

What we offer

- A double PhD diploma from USPN and POLIMI within the French-Italian University;
- An international research environment between dynamic laboratories in France and Italy;
- A multidisciplinary research topic covering physics, materials science and nanotechnology;
- Collaboration with different national and international institutions and with Prof. Jang-Ung Park (Yonsei University, Rep. of Korea) for fabrication of devices based on TFMGs.
- Possibility to follow French and Italian classes and career development courses.

Profile

Master degree in physics or materials science or similar disciplines obtained with high grades.

Further information and application

For further information and application please send your CV, your exam scores (bachelor and master) and max 2 reference contacts/letters to:

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The PhD student will apply to both at “Ecole Doctorale Galilée” ED 146, Université Sorbonne Paris Nord (ecoledoctorale.galilee@univ-paris13.fr) and to “Dottorato in Scienze e Tecnologie Energetiche e Nucleari”, Politecnico di Milano (phdschool@polimi.it).