

# Improving the ductility of bulk metallic glasses by rejuvenation

## Context:

Bulk metallic glasses (BMG) have remarkable structural and mechanical properties due to the absence of long-range order: high toughness, exceptional mechanical strength, elastic deformation almost ten times larger than their crystalline counterparts, which has made them a subject of study since the 90s. On the other hand, the Achilles heel of these materials for engineering applications is their low ductility at room temperature. As a clear structural description of the BMG is still absent, their deformation mechanisms are far from being understood. To better understand the physical and structural mechanisms underlying the mechanical behavior of BMG, it is necessary to analyze the factors that influence the elastic and plastic deformation of these amorphous materials. Although experimental techniques have been developed to progress in the field, these methods often have limitations due to the extreme fragility of the glasses and the difficulty to visualize the atomic rearrangements responsible for the observed behavior. For this reason, modelling approaches are increasingly used to easily access the atomic scale and analyse the local dynamical movements that are responsible for the mechanical behavior in the elastic and plastic regime. This approach will be pursued in the proposed thesis in order to better establish a link between the local atomic dynamics, the material microstructure and the observed mechanical properties.

## Topic and objectives:

This thesis project is in line with three previous PhD projects carried out at MATEIS laboratory at INSA Lyon, in the framework of the CSC program. In our previous work we have established a framework to investigate the atomic-scale plasticity of BMG. In this PhD thesis we will extend this approach to BMG submitted to mechanical and thermal pre-treatment in order to understand the signature of rejuvenation on the small-scale plasticity.

The aim of this project is to analyse the mechanical behavior of BMG in the elastic and plastic regime to identify the physically relevant mechanisms of plasticity at the molecular scale and to assess under which conditions the system can be rejuvenated in order to enhance its ductility. Based on recent experimental works proposing to improve ductility by applying thermal cycles at very small temperatures or by elastostatic loading of the sample, the PhD thesis will focus on the following objectives:

- 1) Set up and analyze a model for a BMG submitted to a thermal cycle and conclude about the parameters and the mechanisms responsible for rejuvenation.
- 2) Perform a parametric study of the effect of different mechanical pre-treatments (static loading, cyclic loading) on the mechanical behavior of BMG to see under which conditions rejuvenation can be obtained.
- 3) Analyze the small-scale plasticity of the systems by using an ad-hoc algorithm that we have recently developed in collaboration with Tristan Albaret (Professor at Lyon 1 University) in order to link the observations of points 1 and 2 to the atomic-scale dynamics.
- 4) Rationalize the obtained results in terms of phenomenological models describing the plasticity of amorphous materials.

**Contacts:** Claudio Fusco: [claudio.fusco@insa-lyon.fr](mailto:claudio.fusco@insa-lyon.fr)

Laurent Chazeau: [laurent.chazeau@insa-lyon.fr](mailto:laurent.chazeau@insa-lyon.fr)