



## PhD Thesis : Institut de Physique de Rennes

### **Subject title : Rheology of glasses out of their thermodynamic equilibrium, using dynamic methods**

#### **Scientific background :**

Inorganic glasses are very common materials of everyday life (building, cars, dishes, smart-phones, screen...), but also used in high technology areas (optical fibers, solar panel, fuel cells...). It is a crucial point to understand their rheology (the way they deform at high temperatures), especially for industrial applications. Indeed, they are amorphous materials, out of thermodynamic equilibrium, so that, below their glass transition temperature, their mechanical properties continuously evolve. Above this temperature, they can crystallize. All these phenomenon impact on their viscoelastic properties. Bulk glasses need to be annealed, in order to relax their internal stresses, and this stress relaxation is mainly controlled by their out-of-equilibrium viscoelastic properties. Inorganic glasses are brittle, so that their are mainly shaped at high temperature through viscoelastic deformation. These are examples of reasons why we need to understand their rheological properties.

Nevertheless, up to now, the viscoelastic properties are poorly understood, and the experimental means to measure them poorly developed (compared with other properties). In the department Mechanics & Glasses of the Institute of Physics of Rennes, we use a dynamical method called RFDA (Resonance Frequency and Damping Analysis), in order to analyze the evolution of viscoelastic properties of glasses in their glass transition domain, *versus* time and/or temperature or above the glass transition, when crystallization occurs. These analyses allows the identification of the microscopical mechanisms involved, their kinetics, their characteristic (activation energy) and how they impact on the macroscopical properties of glasses. These analyses rely on viscoelastic models and mechanical resonance.

#### **Objective of the PhD work**

The PhD thesis will be focused on inorganic glasses : silicate, phosphate and chalcogenide glasses, covering, thus, a wide range of thermodynamic fragility, and allowing the investigation of the impact of small to large composition changes. The PhD student will have to use various experimental technics (RFDA, DMA, viscosimetry, dilatometry, DSC, NMR, Raman spectroscopy...), in order to investigate the structural relaxation or the crystallization and to correlate thermodynamical/structural changes to viscoelastic properties. A large part of this work will be focused on the RFDA and the development of models (numerical, analytical) which will enable as much information as possible from experimental measurements. The PhD student will also develop experimental protocols and experimental design in order to obtain relevant information from RFDA.

## Collaborations

This PhD work is a collaboration between the Department Mechanics & Glasses of the Institute of Physics of Rennes (UMR UR1-CNRS 6251) and the Glasses & Ceramics Group of the Institute of Chemical Sciences of Rennes (UMR UR1-CNRS 6226).

## Expertise complementarity of the Phd supervisors

Fabrice Célarié : RFDA, dilatometry,

Yann Gueguen : viscosity, viscoelasticity, model,

Jean Rocherullé : glass synthesis, structure, calorimetry, crystallization.

## Key-Words

Glass, Viscoelasticity, Resonance, Aging, Relaxation

## Field of Sciences

Material Sciences, Mechanics of Materials, Glasses.

## Funding

Ministerial funding, acquired. Net salary : 1421,84€ per month.

## Bibliography

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