Scale effect in mechanics of semicrystalline polymers: contribution of atomic force microscopy and nanoindentation

This PhD project is a collaboration between two teams of the Institut Pprime laboratory situated in Poitiers, France. It benefits of the complementarity of the competences of the team "Damage and durability" on the relations between microstructure and mechanical behaviour of polymers, and the competences of the team "Defect Physics and Plasticity" on the characterisation of mechanical properties of materials at fine scales. The laboratory has gained 30 years of expertise in nanoindentation and atomic force microscopy, the experimental techniques to characterise mechanical properties at nano and microscale, and a number of experimental machines. This PhD is an innovative and ambitious project, which will benefit of cutting-edge equipment to address an original scientific problem. It will be funded by French Ministry allowance (around 1420€ per month) with a start on 01/10/2021. Beyond this particular subject, this PhD work will allow the student to gain a solid competence in experimental mechanics at very fine scales, that can be used in many areas in industrial and academic context.

The thermoplastic semicrystalline polymers have been largely employed due to their good mechanical resistance, low weight, and recyclability. These materials are strongly heterogeneous, since they are formed of amorphous and crystalline zones in a complex arrangement of lamellas of nanometric thickness, which are organised in spherulites of some microns or some tens of microns. This microstructure, that also depends on the crystallisation conditions, strongly affects mechanical properties of the polymers. To optimise their mechanical properties, it is necessary to better formalise the relation between the morphology and constituents' properties on one hand, and the macroscopic response on the other hand. However, this approach bumps into two persistent problems, still not clarified despite different attempts in the last 15 years, which can be reconsidered using recent techniques of nanoindentation and AFM.

Firstly, although there is a consensus around the idea that two phases have very different mechanical properties, they are very difficult to measure directly because of their sub-micrometric scale and the confinement of one phase by the other. The first goal of this project is to access these properties by experimental techniques based on the contact mechanics between a nano or micrometric tip and a polymer. Secondly, the ascent of scales from nano to macroscopic properties has often been treated by modelling approaches, which is very limited by the morphological complexity of the microstructure to describe. To apprehend it experimentally means realising comparable mechanical tests at different scales. Diverse experimental approaches to be used in this project will enable to study the impact of each phase on the behaviour of polymer at different scales. A key question to address in this project will be the type of constitutive behaviour relevant at each scale.

Thus, the recent techniques of nanoindentation and AFM open new perspectives. This study, mainly experimental, will be done at isotactic Polypropylene (iPP), a largely employed and studied in the literature material. After a preliminary bibliographic study, the experimental work will be organised in 3 packages: a preparation of surface and morphological characterisation of samples (e.g., optical microscopy, electronic and atomic force microscopy), a first characterisation of mechanical behaviour by nanoindentation and AFM limited to elastic regime, and then extended to a viscoelastic regime. The results of this work will be presented at national and international conferences and published in scientific journals.

Skills/diploma:

- Master in Mechanical Engineering or Material Science
- A passion for experimental research
- Knowledge in contact mechanics and/or polymer mechanics will be appreciated.

To apply:

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- Detailed CV
- Motivation letter
- List of mark of last 2 years