POLITECNICO DI MILANO

PhD in INGEGNERIA STRUTTURALE, SISMICA, GEOTECNICA / STRUCTURAL SEISMIC AND GEOTECHNICAL ENGINEERING - 41st cycle

BORSE TEF Research Field: MICROSTRUCTURAL ASPECTS OF VITREOUS HUMOUR LIQUEFACTION, TOWARDS INNOVATIVE EYE TREATMENTS

Monthly net income of PhDscholarship (max 36 months)
1800.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	About 20-30% of Italians over 50 years of age (60% over 70) experience degenerative vitreous conditions. This degeneration may cause serious vision-threatening conditions, but its underlying mechanisms may be exploited in innovative treatments. The human vitreous is a collagen-reinforced, hyaluronic hydrogel sensitive to aging. In a healthy vitreous, a stable network of collagen fibrils carries tensile forces and confines the hydrogel to provide the intraocular pressure. When the collagen network degrades, the hydrogel liquefies and the vitreous collapses with drastic loss of mechanical properties, favouring retinal detachment. However, controlled degradation of artificial collagen-based hydrogels may also be exploited for innovative treatments involving a slow and targeted release of drugs. Despite the relevance of vitreous degradation and collapse, the mechanisms underlying its liquefaction are not understood, which sets a barrier in the medical treatment for vitreous degeneration and other posterior eye conditions. The aim of this project is to fill the knowledge gap through a novel, theoretical understanding of the mechanisms of collagen hydrogels deterioration within the human eye. Specific objectives are to: (O1) Develop the first

	micromechanical 3D simulations of collagen hydrogel degradation, liquefaction, and collapse, caused by chemical interactions and mechanical loads; (O2) From the microscale simulations, derive effective constitutive laws for the vitreous, to inform macroscale models of hydrogel degradation both in the vitreous and in synthetic materials for targeted drug release; (O3) Obtain experimental data to calibrate and validate the models, both from literature and dedicated experiments in porcine vitreous (model system of the human vitreous).
Methods and techniques that will be developed and used to carry out the research	To achieve O1, we will create model microstructures of collagen fibril networks and test their mechanical properties using dynamic, HPC simulations (High Performance Computing). The interaction potentials between particles, discretising the fibrils, will be calibrated from literature data to capture the effects of fibril size and chemical composition of the surrounding hydrogel. For O2, we will compute stress-strain curves from the micro-simulations and implement them as constitutive laws in the continuum-based multi-physics software COMSOL, to simulate the varying chemical environment in the eye and in slow drug release systems, leading to gel degradation. For O3, we will use high resolution imaging tools (Optical Coherence Tomography) to validate the microstructures and rheo-mechanical tests to measure storage and loss moduli of pig eyes and of artificial hydrogels for drug release that we will synthesise and test as a proof of concept.
Educational objectives	To educate a researcher able to understand the function of a tissue from the microstructure and to use the most advanced mathematical and numerical tools to address complex multi-physic problems in Solid and Structural Mechanics.
Job opportunities	Employment in advanced materials modelling or advanced biology research centres, university hospitals, health industry (producers of devices for heart, eye,

	prosthetic).
Composition of the research group	1 Full Professors 2 Associated Professors 1 Assistant Professors 1 PhD Students
Name of the research directors	E. Masoero, A. Pandolfi, F. Boschetti

Contacts
enrico.masoero@polimi.it, 02-23994313, anna.pandolfi@polimi.it, 02-23994217, federica.boschetti@polimi.it , 02-23994374,

Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents	--

Scholarship Increase for a period abroad	
Amount monthly	900.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information

Educational activities (purchase of study books and material, funding for participation to courses, summer schools, workshops and conferences): financial aid per Ph.D. student per year. The Ph.D. course supports the educational activities of its Ph.D. students with an additional funding equal to 10% of the scholarship, for each year.

Teaching assistantship: availability of funding in recognition of support to teaching activities by the Ph.D. student Ph.D. students are encouraged to apply, upon prior authorization, to the calls to support teaching activities at the undergraduate and Master levels at Politecnico, being paid for that. The teaching assistantship will be limited up to about 80 hours, maximum half of them devoted to teaching and classroom activities and the rest to support classworks and exams.

*Computer availability***:** Each Ph.D. student has his/her own computer for individual use.

*Desk availability***:** Each Ph.D. student has his/her own desk, cabinet and locker.


POLITECNICO
MILANO