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ECXX_LABYY_ NOMChercheur_ Numer
ECXX = ECLi, ECL, ECM, ECN, CS
LABYY = acronyme du laboratoire
NOMChercheur = nom du chercheur émetteur du sujet
Numer = numéro de la proposition (01, 02, ….) pour le chercheur

PhD Proposal 2017

School: Central Lille	
Laboratory: LIA LICS **IEMN UMR CNRS 8520**	**Web site: www.iemn.univ-lille1.fr**
Team: AIMAN-FILMS	**Head of the team: Pr. Philippe PERNOD**
Supervisor: Stefano GIORDANO	**Email:** stefano.giordano@iemn.univ-lille1.fr
Collaboration with other partner during this PhD: **In France:**	**In China:**

Title: Modeling the mechanical properties of natural fiber bundle assemblies
Scientific field: Physics, Mechanics, Biophysics
Key words: Fiber bundle, Heterogeneous material, Homogenization, Optimization

Details for the subject:

(Maximal length of 2 pages, including images, list of reference, …The *pdf file* *should* *not* *exceed 1Mo)*

Background, Context:

The Joint International Laboratory **LIA LICS** results from more than 16-years scientific collaboration established since 1996 from French side by the Institute of Electronics, Microelectronics and Nanotechnology (IEMN-UMR CNRS 8520) / EC Lille and from Russian side by the Wave Research Center of A. M. Prokhorov General Physics Institute of Russian Academy of Sciences (WRC GPI RAS). The initial field of collaboration was focused on nonlinear magneto- acoustics of solids and applications in ultrasonics. In 2004 the collaboration was framed within the European Associated Laboratory on Nonlinear magneto-acoustics of condensed matter (LEA LEMAC). The Joint International Laboratory **LIA LICS** between France, Russia and Ukraine on "**Critical and supercritical phenomena in functional electronics, acoustics and fluidics**" is a new LIA project for period 2013-2016 and 2016-2019, with enlarged and strongly renewed scientific scope. It is constructed on the core part of the partnership established during the 1995-2012 years, but presents slight evolutions of the members in accordance with the new scientific program. The laboratory is dedicated to studies of static, quasi-static and dynamic critical and supercritical phenomena in multi-physic fields of functional electronics, acoustics and fluidics. The fundamental investigations are focused on specific features of coupled nonlinear systems near equilibrium and non-equilibrium phase transitions. Three hot topic objects of studies are defined as follows: ***1) Multistable & bosonic micro/nanostructures; 2) Critical State (CS) materials, composites & soft structures; 3) Functional micro-fluidics & interface dynamics***. The subject of this PhD is in close connection with the strategic axis *2)* of the LICS scientific project.

Research subject, work plan:

Natural and biological bundle structures exhibit extraordinary mechanical properties, being able to combine large strength and high toughness. These properties are exploited in eukaryotic cells and tissues, e.g. by cytoskeletal proteins, F-actin, microtubules, spider silk, collagen, muscle sarcomer and so on (see Fig.1). By examining the heterogeneous and hierarchical microstructures of these systems one could argue that the inhomogeneity is the principal ingredient at the origin of these exceptional properties. Also, the introduction of a random and disordered structures can serve to improve mechanical performance. However, a full understanding of the underlying mechanisms remains to be established and it should be investigated with the aim of interpreting the behavior of biological complex structures and of replicating their performances in artificial nanocomposites. While the effects of a population of cracks have been largely studied in homogeneous bundle structures, the effects of cracks or other defects in heterogeneous systems must be carefully considered [1,2]. **Indeed, the aim of the present PhD proposal is that of studying the degradation of heterogeneous bundle systems induced by a population of cracks.** This population of cracks can be generated either by external actions (antibiotics in tendon collagen, lysis of muscle sarcomeres produced by some statins, damage in the form of single-and double-strand breaks in DNA irradiated by high-energy photons in cancer radiotherapy) or by the mechanical load directly applied to the bundle. In the case of external actions, the distribution of fibers is typically uniform within the affected region of the bundle. On the other hand, when the responsible of the damage is the applied load, we consider a number of fibers with statistically distributed strength and the failure process is described as follows: when an external load produces the failure of a fiber, its fraction of load is equally redistributed among all the intact fibers (global load sharing); another redistribution strategy is the so-called local load sharing, stating that the load of a broken fiber is carried only by the nearest intact fibers. These schemes are typically implemented within the so-called fiber bundle model [3,4]. Concerning heterogeneous fiber bundles, only the effective elastic response has been analyzed, without taking into account the possible damage processes [5]. The PhD activity will consist in developing theories and models (also at numerical level) of the degradation processes of the elasticity of heterogeneous fiber bundles or natural origin induced by cracks or defects. Being the activity mainly theoretical and/or numerical, the good candidate should have a strong background in physical and mathematical subjects and he/she should be strongly motivated to perform theoretical (original calculations) and numerical (mainly MATLAB implementations) jobs. In particular, the candidate is expected to have a good knowledge of mechanics of solids, statistical mechanics and MATLAB programming.

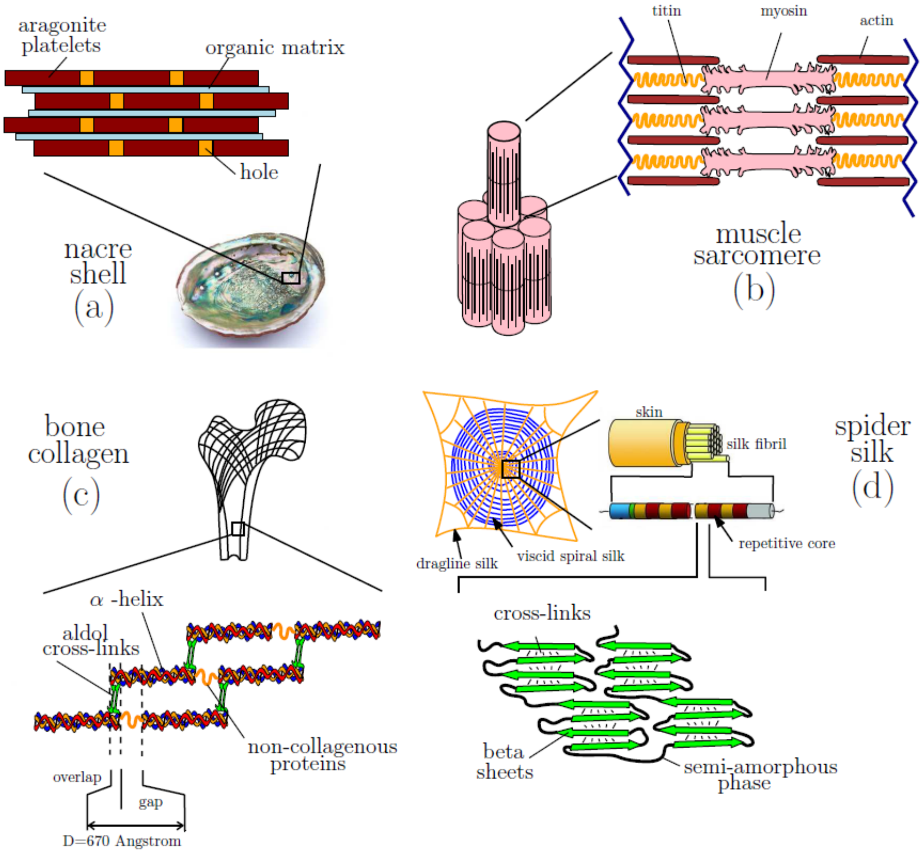

Fig.1. Architectures of biological materials. Panel (a): bricks-and-mortar structure of nacre (or mother-of-pearl). Panel (b): structure of the muscle fibers based on the sarcomere unit. Panel (c): collagen structure. Panel (d): schematic orb-web built by a spider composed of fibers with a skin-core structure.

References:

1) Fabio Manca, Stefano Giordano, Pier Luca Palla, and Fabrizio Cleri, Scaling Shift in Multicracked Fiber Bundles, Phys. Rev. Lett. 113, 255501 (2014).
2) Fabio Manca, Stefano Giordano, Pier Luca Palla and Fabrizio Cleri, Stochastic mechanical degradation of multi-cracked fiber bundles with elastic and viscous interactions, The European Physical Journal E (EPJE) 38, 44 (2015).
3) S. Pradhan, A. Hansen, and B. K. Chakrabarti, Failure processes in elastic fiber bundles, Rev. Mod. Phys. 82, 499 (2010).
4) H. Kawamura, T. Hatano, N. Kato, S. Biswas, and B. K. Chakrabarti, Statistical physics of fracture, friction, and earthquakes, Rev. Mod. Phys. 84, 839 (2012).
5) Fabio Manca, Pier Luca Palla, Fabrizio Cleri, Stefano Giordano, Characteristic lengths in natural bundle assemblies arising from fiber-matrix energy competition: A Floquet-based homogenization theory, European J. of Mechanics - A/Solids (2016).