Research projects 2019-2020

Master Physics of Complex Systems

Biomechanics of cancer cells

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Project description Mechanotransduction describes the molecular mechanisms by which cells respond to changes in their physical environment by translating mechanical stimuli into biochemical signals [1]. These mechanical changes or stimuli can be either forces exerted on the cell from the environment or intracellular forces arising from cell responses to stiffness or topography modifications. The mechanical properties of cells are mainly determined by the cytoskeleton and nucleus, and are essential in major cell functions such as homeostasis, growth, division and motility. During cancerization, the cytoskeleton and lamins, that are giving its rigidity to the nucleus, are directly modified. Recent studies suggest that cancer cells acquire specific mechanical properties allowing them to deform more strongly than healthy cells [2].

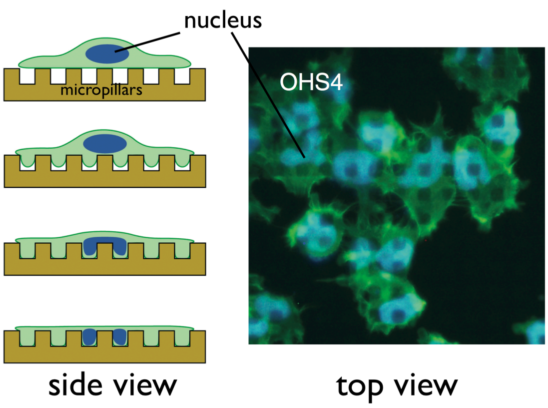

***Figure 1**: Osteosarcoma cells deform to adapt their environment, here patterned micropillars [3].*

This hypothesis was verified using osteosarcoma cells from bone cancer. It was found that the cytoplasm and the nuclei deform considerably when deposited on patterned substrates (Fig. 1). In contrast, healthy cells do not deform and remain at the top of the pillars [3].

Cell Biomechanics Rheology is the study of flow and deformation of fluids when they are submitted to mechanical stresses. Conventional rheometers determine the relationship between strain and stress in steady or oscillating flow on samples of a few milliliters. µ-rheology in contrast studies the motion of micron-size probe particles that are thermally fluctuating *via* the interactions with a surrounding medium, or particles that are forced by an external field. We designed innovative micron-size probes in the form of elongated wires (Fig. 2). Their mechanical and magnetic properties allow to perform passive and active µ-rheology in confined environments [5-7].

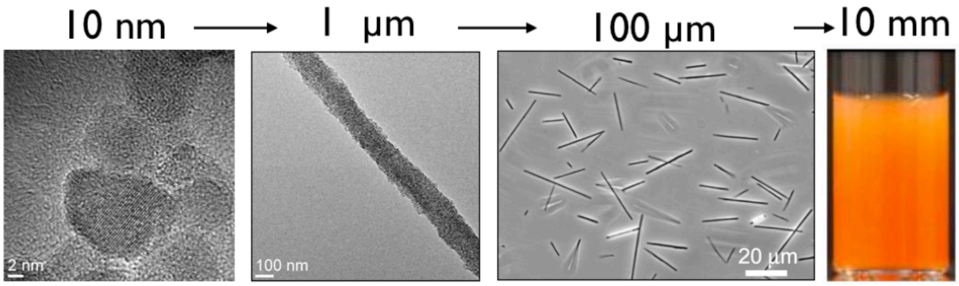

***Figure 2** : Electron-optical microscopy images of magnetic nanowires at different scales [5-7]*

Magnetic wires of diameter 0.5 - 1 µm and length 1 - 10 µm are produced following a novel bottom-up self-assembly method. Complete proof-of-concept studies confirm that this technology is capable of measuring the viscosity of fluids with accuracy. The technique will be applied to healthy and cancerous osteosarcoma cells of different metastatic grades. Experiments will be also performed on the cell nucleus, which viscosity properties are not yet known.

More specifically, the work will deal with i) the synthesis of magnetic/fluorescent nanowires, ii) the internalization and the tracking of wires by optical microscopy, iii) the measure of the deformability and of the viscosity of the interior of cells (cytoplasm and nucleus), cancerous and healthy using a multi-scale approach (pillared substrate and nanowires) and the identification of the cytoskeleton network associated with cell mechanics. During this internship, the student will have the opportunity to learn different techniques of physical-chemistry and biophysics, including the manipulation of nano/bio materials at the cellular level, optical microscopy, cell culture and magnetism.

References on this work

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