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Magnetic nanoparticles and cell mechanics: towards magneto responsive substrates for cells

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Superparamagnetic iron oxide nanoparticles (SPIONs) are a new class of nanomaterials characterized by the ability to convert magnetic energy into heat. For this reason, they have been found to have interesting applications in various fields of technology; in particular, they are applied in medicine as diagnostic and therapeutic agents. Furthermore SPIONs can be used as in vitro probes to study cell mechanics, a branch of biology and engineering focused on the relation between cell structure and forces.

The main aim of this PhD thesis is to investigate SPIONs for cell mechanics. Specifically, to develop and characterize SPIONs-based cell culture substrates that change their mechanical properties in presence of a magnetic field, and to study the effect of magnetic stimulation on cell mechanics.

To do so, the first part of the thesis focuses on synthesis and functionalization of SPIONs and on the optimization of their heating ability. Specifically, the enhancement of SPIONs heating properties through post-processing treatments is demonstrated and this method can also be used to simultaneously stabilize the nanoparticles in biologically relevant solvents. The theory behind a newly developed method for the study of the heating power of SPIONs is also presented and, using this method, some potential sources of errors in the quantification of SPIONs heating power are investigated.

Subsequently, the synthetized SPIONs are incorporated in a polymeric matrix and used as magnetic actuators to trigger conformational and mechanical changes in cell culture substrates. The magnetic field responsiveness, the composition, the biocompatibility and the mechanical properties of these materials are then investigated. Furthermore, the effect of magnetic stimulation on the mechanical properties of the substrates is studied on fibroblast cells by analyzing cell morphology with confocal laser scanning microscopy.

The final part of the thesis aims to highlight the importance of an appropriate surface mechanical characterization of cell substrates in their pristine environment, i.e. liquid. Indeed, knowing the elasticity and the viscosity of these materials is fundamental to correlate the substrates to the cellular behavior. For this reason, this final part focuses on the use of Intermodulation AFM, a quantitative atomic force microscopy method, in liquid. In particular, experiments on polymeric blends and simulations that validate the use of Intermodulation AFM in liquid environment are provided, thus setting the stage for future investigation of cell culture substrates in liquid.

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