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Light-sensitive Nano and Microstructures based on Conjugated Polymers: Optical control of the Cell Fate

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Use of light for selective and spatio-temporally resolved control of cell functions (photoceutics) is emerging as a valuable alternative to standard electrical and chemical methods. Here, we propose the use of organic semiconductors as efficient and biocompatible optical transducers, and we focus in particular on breakthrough applications in the field of regenerative medicine.

Devices able to selectively and precisely modulate the fate of living cells, from adhesion to proliferation, from differentiation up to specific function, upon visible light will be presented and critically discussed. Examples of practical applications, recently reported by our group, include optical modulation of the activity of both excitable and non-excitable cells, control of essential cellular switches like transient receptor potential channels and other cationic channels, as well as effective modulation of intracellular calcium signalling for precise control of cell metabolic processes.

We will describe fabrication and optimization of micro- and nano-structured polymeric interfaces, in the form of beads and 3D scaffolds, with different cell models.

As representative examples, we report on (i) functional interaction with intracellular proteins, leading to non-toxic modulation of the cell metabolism; (ii) a novel strategy to gain optical control of Endothelial Progenitor Cell (EPC) fate and to optically induce angiogenesis in vitro; (iii) optical modulation of mesenchymal stem cells and human-induced pluripotent stem cells physiological pathways; (iv) effects of light-sensitive 3D scaffolds on neuron and astrocyte cell models.

Current knowledge about the photo-activated processes occurring at the conjugated polymer/living cell interface, obtained by complementing several physical/chemical/biological characterization techniques, will be extensively discussed.

The above mentioned study-cases represent, to the best of our knowledge, first reports on use of organic semiconductors for optical modulation of the cell fate, with disruptive perspectives in cell-based therapies. Future opportunities for further implementation of the optoceutic technique and its perspective applications in regenerative medicine will be critically evaluated in the conclusions.