Controlling Life with Photons

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Use of light for controlling the electrical activity of living cells and tissues is emerging as a valuable alternative to standard electrical methods, able to overcome many current limitations. Cell optical stimulation offers unprecedented temporal and spatial resolution, and a virtually infinite number of configuration, free from wiring constrains. Several strategies have been proposed, either exploiting photoactive mediators nearby or within the cells (photoisomerizable or photocleavable compounds; infrared neural stimulation, genetic expression of sensitive probes), or using photoactive materials placed externally, close to the cell, and able to transduce light excitation into an electrical, chemical, or thermal stimulus.

In our work [1,2] we first proposed the use of organic semiconductors as efficient optical transducers. We demonstrate that conjugated polymers can be used to achieve full-optical control of cell activity, in terms of both excitation and inhibition [3,4]. We report examples of functional interfaces between several combinations of conjugated polymers and different cell cultures (HeK cells, astrocytes, neuronal networks) [5]. A detailed model of the mechanisms occurring at the polymer/electrolyte interface and leading to living cell photoexcitation, based on electrical and optical measurements, will be presented and critically discussed.

The most direct application of the polymer-based cell photostimulation protocol is in the artificial visual prosthetics: recent results of in-vivo implantation in rats of organic-based artificial retinas will be presented and critically evaluated [6,7]. Finally, we will propose exogenous stimulation strategies alternative to the use of planar thin films, based on the injection of nanoparticles into the living cell. Preliminary studies of this approach applied both to single cells and to simple animal models will be presented, aimed at identifying the best materials candidates in terms of bio compatibility and functionality.

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