# Bio-Polymer Interfaces for Optical Cellular Stimulation: a Computational Modeling Approach

**Matteo Porro**[(1,2)], **Sebastiano Bellani**[(2,3)], **Nicola Martino**[(2,3)], **Guglielmo Lanzani**[(2,3)], **Maria Rosa Antognazza**[(2)], **and Riccardo Sacco**[(1)]

(1) Dipartimento di Matematica, Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133 Milano, Italy

(2) Center for Nano Science and Technology @PoliMi, Istituto Italiano di Tecnologia, Via Pascoli 70/3, 20133 Milano, Italy

(3) Dipartimento di Fisica, Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133 Milano, Italy

e-mail: riccardo.sacco@polimi.it

In this contribution we illustrate our latest results on the investigation and mathematical description of the physical processes underlying the behaviour of a particular bio-polymer interface device for optical cellular stimulation [1]. The device consists of a thin layer of P3HT, a photoactive semiconducting conjugated polymer, deposited on a transparent electrode, with a cell grown on top of it. The whole system is immersed in a physiological solution to allow cell survival. Despite a significant electrical cellular activity is elicited upon device illumination [2], the physical processes driving the induced cellular response, possibly involving electric and thermal phenomena, are still not fully understood.

In order to investigate the role played by electrical effects in device operation, a characterization of the electric response of the substrate is carried out with transient photovoltage measurements. Then a suitable PDE model is proposed starting from the state of the art approach for organic photovoltaic devices, including the description of injection/recombination current balance at the electrode, energetic disorder and charge trap dynamics. Both experimental and simulation results consistently indicate that upon illumination, free charges are generated and displaced by an electric field, resulting from the onset of a depleted region at the P3HT/electrode interface, with characteristic time scales dominated by charge trap dynamics.

However, with more intense light input, absorption induced temperature increase in the system becomes increasingly important. This effect has been proven in [3] to modify cell membrane capacitance and recently addressed as responsible for cell depolarization in the patch clamp measurements of [4]. To support this physical picture, a lumped parameter circuit model is proposed to describe cell membrane response, including appropriate constitutive laws for membrane properties as a function of local temperature [1, 4].

The main conclusion of the present investigation is that bio-polymer interface device operation is driven by both electric and thermal phenomena, which are dominant at low and high light input, respectively.

## References

[1] M. Porro, Bio-Polymer Interfaces for Optical Cellular Stimulation: a Computational Modeling Approach, *PhD thesis*, Politecnico di Milano, (2014).

[2] D. Ghezzi, M.R. Antognazza, M. Dal Maschio, E. Lanzarini, F. Benfenati, and G. Lanzani, A hybrid bioorganic interface for neuronal photoactivation, *Nature Commun.*, 2, 166 (2011).

[3] M. G. Shapiro, K. Homma, S. Villarreal, C. P. Richter, and F. Bezanilla. Infrared light excites cells by changing their electrical capacitance. *Nature Communications*, 3:736, 2012.

[4] N. Martino, P. Feyen, M. Porro, C. Bossio, E. Zucchetti, D. Ghezzi, F. Benfenati, G. Lanzani, and M. R. Antognazza. Mechanisms of cell stimulation in photoactive bio-polymer interfaces. *submitted to Scientific Reports*.