Nano harvesting energy applied to cell biology

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Abstract

Our bodies are complex machines whose functioning depends on multiple electrical signals controlled mainly by the nervous system. Afterwards, it is not illogical to think that one day artificial electrical impulses would replace those signals offering support to medical treatments. Nowadays electrical stimulation is used in many therapeutic applications to modulate cellular activity, restore biological lost functions or even improve the performance of certain tissues. However, these systems still carry side effects link to the surgical interventions to place them or place their electrodes, their inherent bulkiness or lack in specificity to target only the cells involved in the condition to treat. The future to transcend these constrains would be possible in the extent that technology ease the path to improve precision, autonomy and miniaturization of the actual therapeutic tools. In this context, micro/nanogenerators play a key role as self-powered devices with high spatial resolution and acute cell specificity.

This work aims to provide micro/nanogenerators to stimulate single cells in its own liquid media. This work explored two technological branches based on photovoltaic and on magnetoelastic (piezoelectric/magnetostrictive) devices to harvest energy. Their fabrication was accomplished through micro/nanosystems technologies and their performance was characterized through several tests to ensure their correct power generation. As these devices were intended to interface biological media, direct cytotoxicity studies were conducted to guarantee their safety. Both branches were biologically validated with *in vitro* models of excitable cells (human osteoblast-like cells) analyzing the electrostimulation effects through morphological changes and through instantaneous ionic responses as calcium signaling.

Here, we demonstrate that the interaction of human cells with piezoelectric nanogenerators (NGs) based on two-dimensional ZnO nanosheets (NSs) induces a local electric field that stimulate and modulate their cell activity. When cells were cultured on top of the NGs, the electromechanical NG-cell interactions stimulated the motility of macrophages and triggered the opening of ion channels present in the plasma membrane of osteoblast-like cells inducing intracellular calcium transients, (activated cells over 62%). In addition, excellent cell viability, proliferation and differentiation were validated [1,2,3].

We will present the technology for microphotodiodes fabrication and the characterization of single microphotodiode characteristics under in vitro conditions. We also demonstrate their capability to harvest energy from light and instantaneously convert it to an electric stimulus. These devices provide a stimulation tool of single cells without the limitation of external cables and electrodes. The electrical stimulation triggered intracellular calcium transients as a response in 46% of the cells. Furthermore, induction of cytosolic Ca2+ transients triggered by the electrical stimuli generated by the microphotodiodes, on which osteoblasts cells were grown, shows the feasibility of this approach towards localized activation of excitable cells in a simple way [4,5].

The results gathered in this research demonstrate the feasibility of these micro/nanogenerators as self-powered electrical stimulators. Furthermore, their reduce size and capability to be suspended in liquid media open the door to further developments towards injected or ingested minimally invasive medical tools.
(*Partial abstract from PhD Thesis of Carolina Vargas-Estévez, Universitat de Barcelona 2019*).

References

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Figures

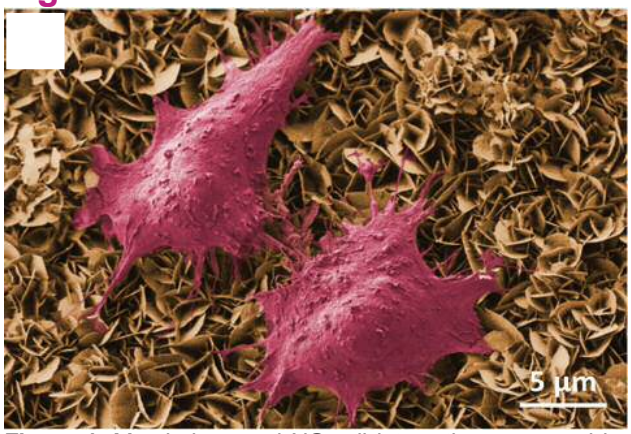

Figure 1. Morphology and NG-cell interaction, assessed by scanning electron microscopy showed that cells were firmly adhered to the nanosheets (NSs) [1]

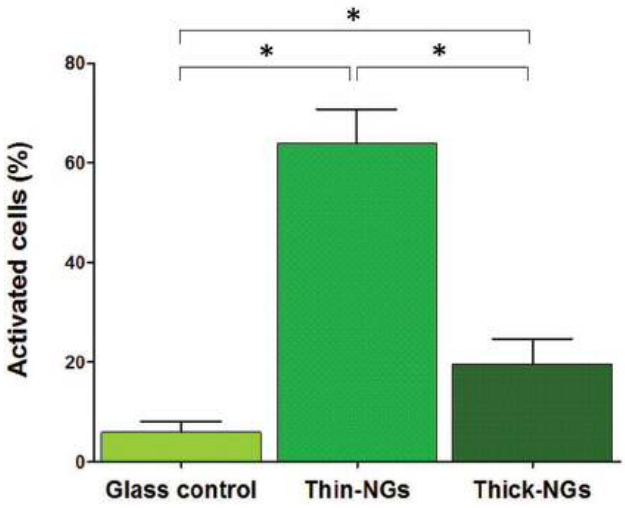

Figure 2. Quantification of Saos-2 cells undergoing changes in Ca2+ concentration (activated cells). Asterisks above the columns indicate significant differences (Kruskal-Wallis test and χ2 test) [1]

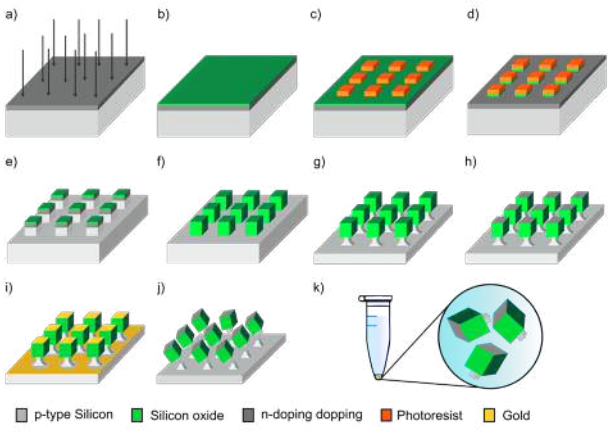

Figure 3. Fabrication process of suspended microphotodiodes [4]

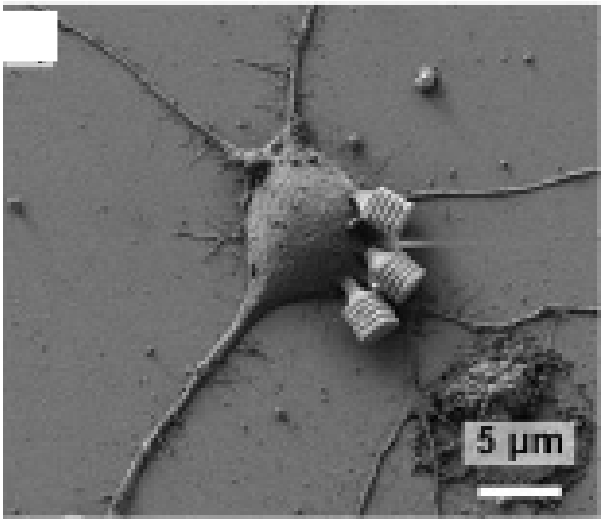

Figure 4. SEM image of neuron with photodiodes attached to soma [4]

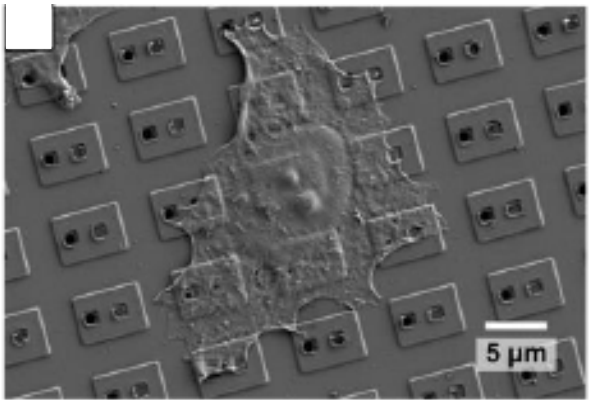

Figure 5. SEM image of Saos-2 cells growing on microphotodiodes array (PVMA). [5]

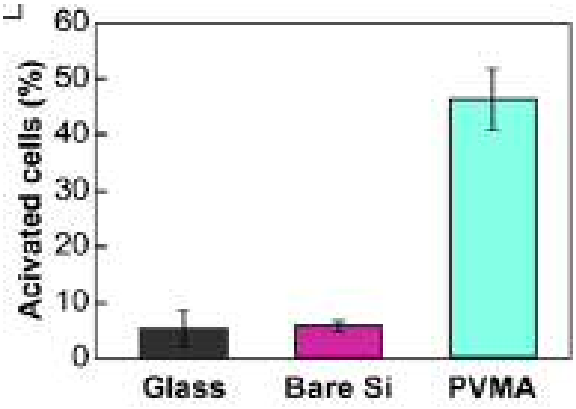

Figure 6. Percentage of activated Saos-2 cells on PVMA and on glass coverslip/bare silicon control for the same light stimulation. [5]