Controlling the membrane potential and stiffness of cancer cells via ferroelectric surfaces

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In the last 10 years, interest has emerged in using ferroelectric materials as virtual electrodes to investigate biological specimens. Effectively, applying a direct electric field to cells often requires using metallic, limited-sized electrodes that are only sometimes biologically compatible. Ferroelectric materials are a promising alternative solution due to their unique, spontaneous electric polarization, as there is no need for an external circuit or electrical source to be used. In this work, we report a new method for investigating the mechanical properties of living cells grown on ferroelectric crystal surfaces with different polarities using a new technique called nanoendoscopy-AFM[1]. This technique allows for inserting an AFM nano-needle inside a cell[2-3] and studying the electromechanical properties of the cell and the nuclear membrane. Our findings suggest that ferroelectric surfaces can be used to modulate the external and internal ionic environment of cells, thus affecting cell stiffness depending on the polarity of the ferroelectric crystal and ionic species around cells. Our proposed models are confirmed via the membrane potential fluorescence dyes and show that ferroelectric surfaces can also trigger the depolarization and hyperpolarization of cancer cells, depending on the polarity of the ferroelectric crystal.

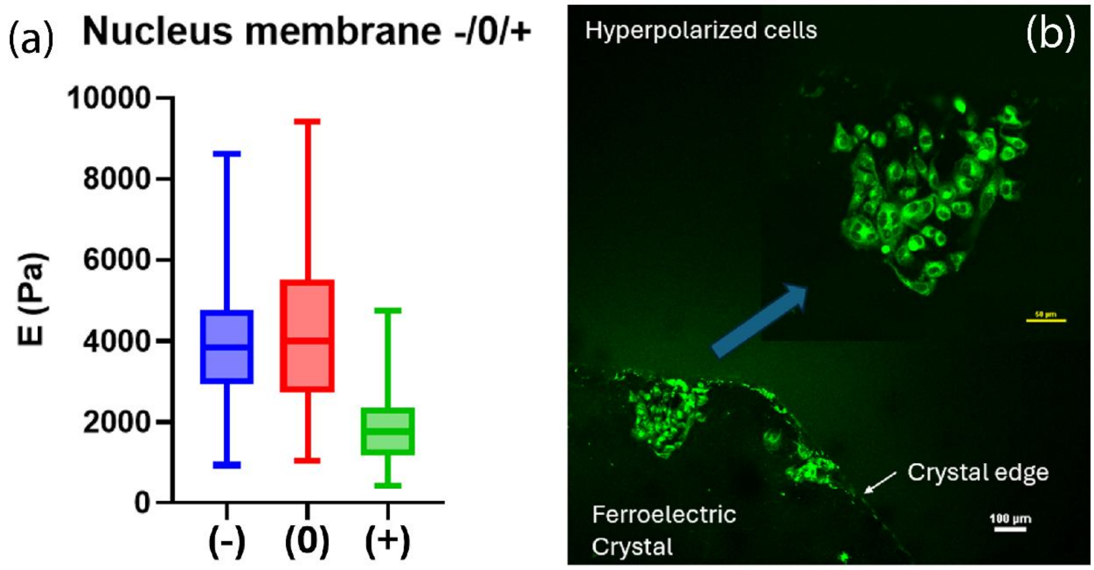

Figure 1. (a) Elastic properties of nuclei grown on a negative (-), neutral (0), and positive (+) ferroelectric crystal surface. (b) Fluorescence microscopy images of cancer cells grown on a ferroelectric crystal in a hyperpolarized state.

Reference

[1] M. Penedo, et al., Sci. Adv.7, eabj4990 (2021).

[2] M. Penedo, et al., Sci Rep 11, 7756 (2021).

[3] T. Ichikawa, et al., STAR Protocols, Volume 4, Issue 3, 102468 (2023).