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AC amplification gain in organic electrochemical transistors (OECTs) for impedance-based single cell sensors

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Research on water-gated and organic electrochemical transistor (OECT) architectures is motivated by the prospect of a highly biocompatible interface capable of amplifying bioelectronic signals at the site of detection. Despite many demonstrations in these directions, a quantitative model for OECTs as impedance biosensors is still lacking.

We overcome this issue by introducing a model experiment where we simulate the detection of a single cell by the impedance sensing of a dielectric microparticle, precisely positioned using an atomic force microscopy cantilever. A schematic of the experimental setup is reported in *Figure 1a.* The highly reproducible experiment allows us to study the impact of transistor geometry and operation conditions on device sensitivity. Measurements are performed with both an OECT and a PEDOT:PSS microelectrode to study the impact of the transistor amplification on the device sensitivity. We rationalize a mathematical model which relates the OECT gain to the applied frequency, the device geometry and PEDOT:PSS materials properties. The main results are reported in *Figure 1b.*

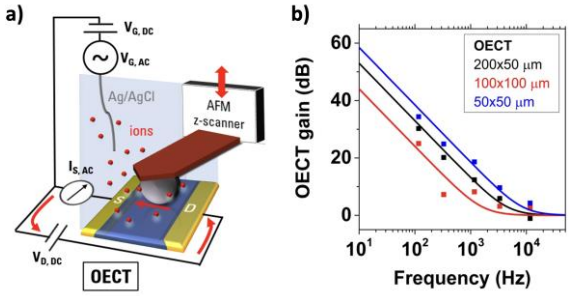

Fig. 1: a) Setup for the model experiment. The microparticle is attached to the bottom part of an AFM cantilever and approached and retracted from the device channel. The current amplitude follows the motion of the microparticle in a highly reproducible manner, allowing for the extraction of the device sensitivity. b) Quantitative analysis of the OECT performance as an impedance sensor. The OECT gain with respect to a PEDOT:PSS microelectrode is plotted as a function of the applied frequency for devices with different channel width and length. The model predictions are indicated with continuous lines, while dots refer to the experimental results.

The model provides clear guidelines for the optimization of OECTs as single cell sensors, and we verify the quantitative predictions in an *in-vitro* experiment. *Figure 2a* reports an optical image acquired during the experiment showing a single cell placed in the center of a PEDOT:PSS-based sensor. The time evolution of the cell adhesion monitored with an OECT and a microelectrode is presented in *Figure 2 b.* In the optimized geometry, the OECT-based impedance sensor allows to record single cell adhesion and detachment transients, showing a maximum gain of (20.2±0.9) dB with respect to a single electrode-based impedance sensor.

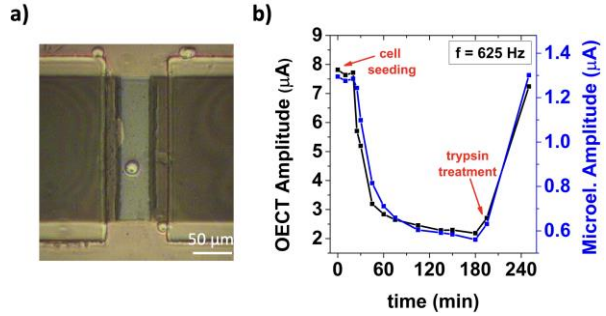

Fig. 2: Single cell detection experiment. a) Microscope image of a single cell placed at the center of a PEDOT:PSS channel with width and length of 200x50 µm, respectively. b) OECT and microelectrode current amplitudes measured at 625 Hz as a function of time. Both sensors are able to measure the cell adhesion after seeding, and recover their original performance after the cell detachment with trypsin.

References:

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