Downscaling Electric Cell-substrate Impedance Sensing: What can transistor devices contribute?

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As an alternative to the classical Electric Cell-substrate Impedance Sensing (ECIS) with metal microelectrodes, electrolyte-gated field-effect transistor (FET) devices can be used. In this case, the transistor-transfer function (TTF) method is applied, where a sinosoidal stimulation voltage is provided to the reference electrode of the 3-electrode transistor configuration and the voltage response of the transistor together with its first transimpedance amplification stage is recorded. Similarly to classical impedance spectroscopy, TTF spectra are recorded representing the bandwidth of the device configuration.

This alternative method offers several advantages: First the input impedance of the transistor is not relevant in this configuration, since voltage changes at the transistor gate are directly transduced into current changes in the transistor channel. Second the transistor's direct current (DC) in its working point is much larger compared to classical currents in ECIS devices and hence much less prone to parasitic effects of the contact lines on chip and peripheral cables. The relevant alternating current (AC) information for cell impedance measurements is carried on top of this large DC current. Third transistor devices permit much larger integration density of many devices on one chip and individual devices can be miniaturized to cellular and even sub-cellular spatial resolution.

In this presentation, different transistor devices will be demonstrated, which were used for ECIS recordings from classical silicon-based ion-sensitive FETs [1, 2], planarized silicon FETs for migration studies [3], silicon nanowire FETs with scaling into the sub-micrometer range to polymer-based electrochemically gated transistor devices [4]. Different cell types from cell lines, primary neurons, heart muscle cells, individually acting immune cells down to erythorcyte ghost cell were utilized for ECIS with transistor devices.

It will be demonstrated that there is even more potential within these devices, if their ion-sensitivity is exploited or the electrochemical adhesion noise is analyzed as additional information relevant to cell adhesion [5].

As a conclusion, transistor devices for ECIS realized with different materials and device concepts offer exciting possibilities for the future of ECIS.

References:

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