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Summary of the Dissertation:

Electrical excitation of biological cell systems with a two-dimensional electrode structure

Abstract

A simple, planar interdigitated stimulation electrode for applications in different biological environments was developed considering essential experimental boundary conditions, i.e. optical transmission, electrical conductivity, withstand voltage and biocompatibility. Experimental results suggest an electrode structure of an 5 nm thin Titan-undercoating followed by a 50 nm thin gold layer deposited by electron beam evaporation.

The experimental setup consisting of a metal electrode, an electrolyte and living cells are electrically characterized for frequency dependent direct and alternating voltage. The successively defined equivalent circuit allows a simulation of the measured impedance to analyze the discrete influence of the electrode, the electrolyte or the biological component and their interdependencies.

Two different biological systems are used to demonstrate the variable adaptability for stimulation experiments. Infect, dissociated neural networks and suspended yeast cells are investigated to determine the excitation parameters, i.e. pulse amplitude, pulse width, and edge steepness.

Synchronous neural network activity is evoked by stimulation with biphasic, 10fold square pulses of an amplitude of ±2.2 V and a pulse width of 1 ms. To analyze the excitation mechanism of single neurons, the present superposed neural activity of directly stimulated neurons and of mediately activated neurons due to synaptical signal transmission has to be distinguished. After blocking the synaptic activity by an addition of antagonists to the glutamate and $GABA_A$ receptors, only direct electrical excitation occurs. Since in synaptically blocked networks that are located 1.5 mm far from the electrode neural activity is observed after an electrical excitation, antidromic stimulation has to be occurred. The stimulation efficiency correlates with the axonal density across the electrode edges, which is the region of highest potential gradient.

The energy metabolism of yeast cells is affected by electrical excitation of single, biphasic square pulses with an amplitude of ±11 V and a pulse width of 4 ms. Additionally, the electrode offers the possibility of an electrical investigation of glycolytic oscillations of yeast cells and yeast extract. Thus, these electrically measured oscillation effects could be correlated to changes in the system impedance or in the membrane conductivity of yeast cells as well as to periodic concentration changes of ionic and dipole compounds from glycolytic intermediates of yeast extract.