Simulation of the Electrode-Tissue Interface with Biphasic Pulse Train for Epi-retinal Prosthesis

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Abstract

Retinitis Pigmentosa (RP) and Age-related Macular Degeneration (AMD) are diseases causing blindness in a large number of people. While RP being a family of inherited disorders and AMD appearing in people in their late 50s, both the diseases affect the retina in a degenerative way which cannot be cured with treatment. Mostly the photoreceptors are damaged due to these diseases, and thus attempts have been made to electrically stimulate the surviving inner retinal neurons and retinal ganglion cells (RGC) in order to restore vision. A group of researchers working in this area, from the University of Southern California started with 4 platinum electrodes that stimulate the RGC with electrical signals. Currently they use a sixty electrode array for better temporal and spatial resolution. This, on human trial, was able to differentiate basic forms of motion, perceive light and dark and even shoot baskets. In this paper, the electrode-tissue interface is modeled to study the effect of electrode size and distance between the electrode and retina by applying biphasic pulse trains similar to those used in in-vitro experiments and in-vivo trials. Simulations were carried out using the AC/DC Module of COMSOL Multiphysics® with planar disc electrodes placed over the constitutive layers of retina. The diameters of the electrodes were varied from 10um to 500um with 100um centre to centre distance. The thickness of the vitreous layer separating the electrode from RGC was varied from 10um to 50um. Biphasic 1 millisecond pulses were applied to the stimulating electrode. Solved for time and frequency domain, electric potential at a point in the RGC layer was found to vary both as a function of electrode diameter and distance of the electrode. The activation criterion for the retinal ganglion cells in this study was considered to be around 1500V/m above which the neurons will be able to generate action potentials. Charge density was well below the safe limit of 0.35mC/cm2 for platinum electrodes. The potential increased gradually with increasing diameter and decreasing vitreous thickness. Figure 1 shows the distribution of electric potential across the retinal layers for the applied biphasic pulse. The current at the RGC layer was found to decrease exponentially with increasing pulse duration which is similar to the strength-duration curve for excitable tissues. The electrode tissue impedance was also observed with varying frequency (1-105 Hz). In-vitro experiments with OCT using 75um diameter inner pole of a concentric bipolar Pt/Ir electrode as stimulating electrode and the 300um diameter stainless steel outer pole of the electrode as the return electrode have shown similar trends [1]. Recent studies have found both amplitude and frequency have effects on percept size [2]. Therefore, this study can throw light on the electric field and charge distribution due to the application of such modulated bi-phasic pulses across the tissue layers. With further extension to 3D geometry, it

will be possible to optimize the electrode geometry for better performances of the retinal implant.

Reference

1. Aditi Ray et al. Impedance as a Method to Sense Proximity at the Electrode-Retina Interface. IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 19, no. 6, December 2011.
2. Devyani Nanduri et al. Frequency and Amplitude Modulation Have Different Effects on the Percepts Elicited by Retinal Stimulation. Investigative Ophthalmology & Visual Science, Vol. 53, No. 1. January 2012.

Figures used in the abstract

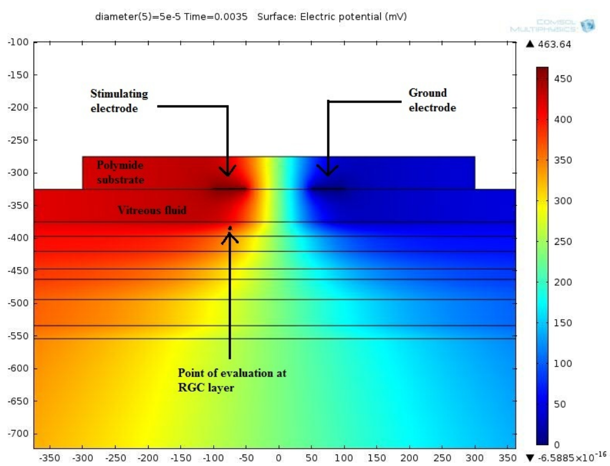

Figure 1: Electric potential distribution across the retinal layers during the positive cycle of the biphasic pulse