Electric Field Density Distribution for Cochlear Implant Electrodes

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Abstract

Cochlear Implants (CIs) are implantable devices which bypasses the non-functional inner ear and directly stimulates the hearing nerve with electric currents thus enabling deaf people to experience sound again. CI electrode array, an important component, lying in close proximity with auditory neurons performing the function of transferring external auditory information to electrical signal through the auditory nerve to the auditory cortex. The present electrodes are a bundle of platinum/iridium (Pt/Ir) wires welded to platinum strips acting as stimulation sites. The current design is limited in electrode count, due to their large size in accordance to scala tympani (ST) with restrictions for deeper insertion in ST thus depriving access to low frequency auditory neurons. The benefit of single site stimulation over multiple sites is to gain the freedom of perceiving multiple frequencies over a broader range to match the so-called tonotopy in the cochlea. Also multiple sites gives the audiologist an extra room for better choice of stimulation pattern, allowing fine-tuning of the device for individual patients. Silicon semiconductor technology provides the fabrication of advanced high-density CI electrode arrays with greater number of stimulation sites, integration of electronics, reduced size, multiplexing and specific site selection as per frequency. This results in less area requirements for placing the device with low power for the electronics and other components. In this paper we present the simulation results for the three different electrode configuration of our proposed design. The basic design of CI electrode array consists of an Silicon substrate with titanium nitride (TiN) stimulation sites [1]. Three different configurations showing the placement of the stimulation site in the Silicon substrate are as shown in Figure 1. These designs are considered prior to the fabrication point of view to study the effect of electric filed density distribution near the stimulation site. This is important since greater electric field in the nearby area of stimulation sites may cause over-stimulation and may lead to residual hearing damage. These field should have sufficient value to trigger an action potential in the nerve, but should also be low in the surroundings to avoid neural damage. COMSOL Multiphysics 4.2a was used to create a cross-section of the electrode array (Figure 2) in a model of the cross-section of the cochlea. The cross-section of the cochlea can be modeled as an rectangle for this purpose [2]. Silicon electrode array base is 20 µm thick with TiN stimulation site of 0.2 µm thick. The electrode array is placed inside the ST which is filled with perilymph [3],a fluid with high K+ and low Na+concentration. The stimulation current for electrodes in our case is modelled as a potential of 544 mV [4]. The bottom of the cochlea model is ground, in reality there will be a extracochlear wire that works as a ground. The placement of the TiN electrode is changed using a parameter sweep, i.e. it is moved in y-

direction, from top till the embedded part completely. From fabrication point of view protruded design was considered in respect to other designs.

Reference

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[4] Tognola, G., Pesatori, A., Norgia, M., Parazzini, M., Rienzo, L. D., Ravazzani, P., et al. (february 2007). Numerical Modeling and Experimental Measurements of the Electric Potential Generated by Cochlear Implants in Physiological Tissues. Instrumentation and Measurement, IEEE Transactions on, Volume:56 Issue:1, 187-193.

Figures used in the abstract

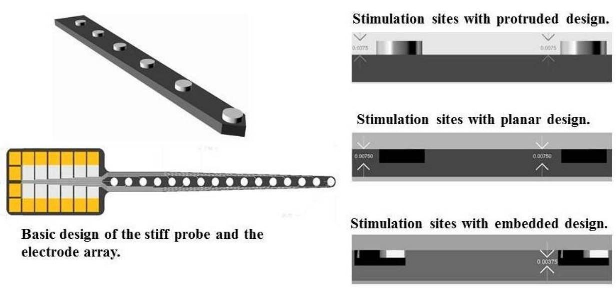

Figure 1: Design for the silicon CI electrode array with different configuration for the stimulation sites.

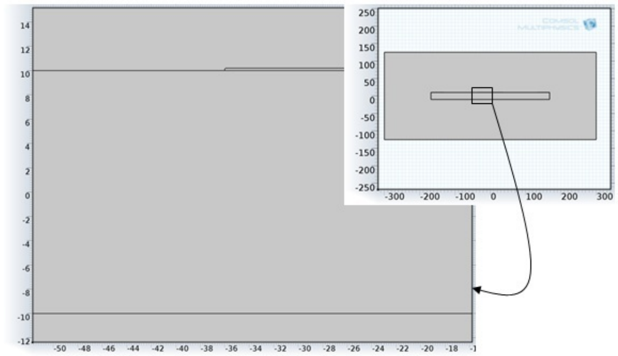

Figure 2: Cross-section of the electrode with an zoomed view of the model.

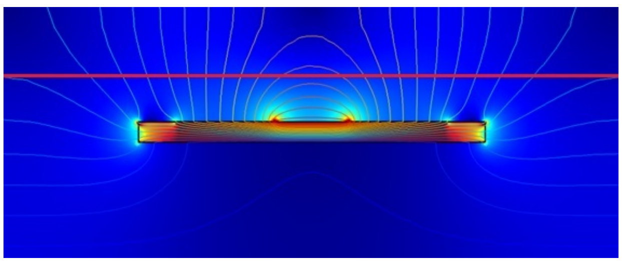

Figure 3: The Electric field distribution of the embedded design. The red line is the cut line used in Figure 4

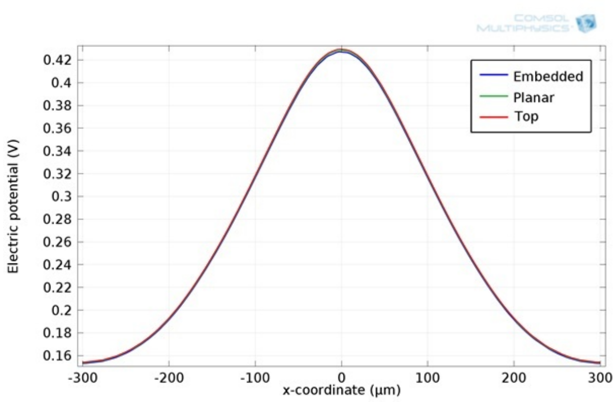

Figure 4: The potential at 50 microns from the top surface of the electrode base.