Electrochemical Study of Potential Materials for Cochlear Implant Electrode Array

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Abstract

Introduction

Cochlear implants (CIs) are commonly accepted therapeutic devices for clinical use and have restored hearing to more than 230,000 profoundly deaf people. CI devices consists of an external part comprising a speech processor (DSP) a microphone which together receive and convert the sound into a digital data stream using a speech processing strategy. The digital data is then transferred via an RF link to the internal part, viz. the receiver-stimulator package, which receives power and decodes the instructions for controlling the electrical stimulation via a multichannel electrode array placed inside the cochlea, giving a rich and natural perception of sound [Fig.1].

The CI electrode array is an important component of the implant device which sits inside the cochlea close to the auditory neurons passing the external auditory information to the auditory cortex. Over the past decades, the design of these electrodes has developed from simple single channel devices to multiple site arrays consisting of 12-22 stimulation sites fabricated using metallic wires made of different materials for neural applications [2]. These metallic wires are connected to square metallic strips of 0.4mmx0.5mm which act as stimulation and which are responsible for transferring electric charge to the neurons. Platinum is the common material used for making these electrodes. An ideal stimulation material must have low impedance with maximum charge transfer capacity in the electrochemical environment of cochlea. These materials must not only withstand this harsh environment but also transfer maximum charge without damaging tissue.

Use of COMSOL Multiphysics®

This paper investigates potential materials like Ti, TiN for electrochemical stability. By using the Electrochemistry Module of COMSOL Multiphysics® 4.3b an estimation can be drawn from the cyclic voltammetry (CV) which gives knowledge on charge injection capacity. CV is a three-electrode measurement in which the potential of a test electrode, with respect to a noncurrent-carrying reference electrode, is swept cyclically at a constant rate between two potential limits while allowing current to flow between the test electrode and a counter electrode. It is common practice to characterize stimulation electrodes by their cathodal charge storage capacity (CSC). The CSC is calculated from the time integral of the cathodic current in a slow-sweep-rate cyclic

voltammogram over a potential range just within the water electrolysis window [3].

In COMSOL Multiphysics® 4.3b a simple single-electron reaction is modelled at the electrolyte interface of a circular titanium electrode with a radius of 1mm. We have assumed standard reactions occurring at the interface in order to predict the Charge Transfer Capacity for different shapes and sizes of the electrodes. The counter electrode is a platinum plate. The solution is water with a given concentration of the reactant. The geometry is a 2d axis symmetric, resulting in a cylindrical electrochemical cell [Fig.2]. The applied potential is a triangular wave (-0.3V to 0.3V and back to -0.3V). Before the simulation a free triangular mesh with sufficient elements is chosen as shown in Fig.3. The resulting CV for Titanium in the applied potential range is as shown in Fig. 4. The area under the curve gives the information of the charge injection capacity for Titanium material.

Reference

[1] Figure from Advanced BionicsTM: http://www.advancedbionics.com

[2] D. J. Anderson , K. Najafi, K. D. Wise, "Batch-Fabricated Thin-film Electrodes for Stimulation of the Central Auditory System," IEEE Trans on Biomedical Engg. Vol. 36, No. 7, July 1989, pp. 693-704.

[3] S. F. Cogan, "Neural Stimulation and Recording Electrodes", Annual Review Biomedical Engineering Vol. 10 (2008), pp. 275-309.

Figures used in the abstract

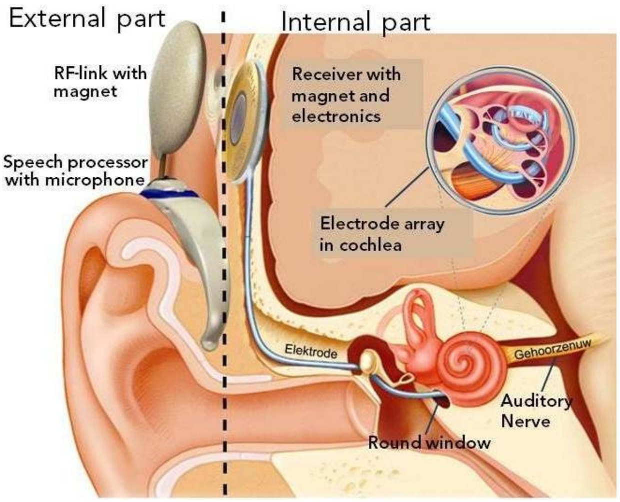

Figure 1: Figure 1. Cochlear implant with microphone, transmission coil, receiver- stimulator and electrode array fitted inside the cochlea.

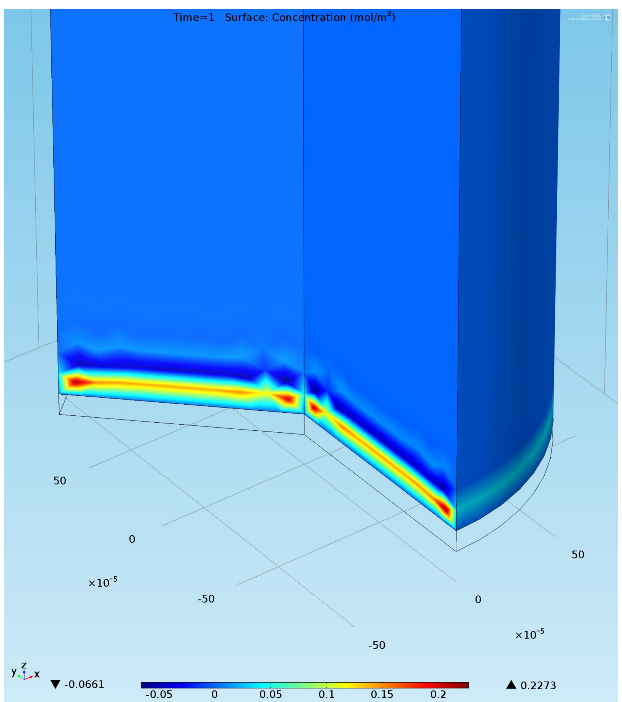

Figure 2: 2D axis symmetric representation of the electrode-electrolyte interface.

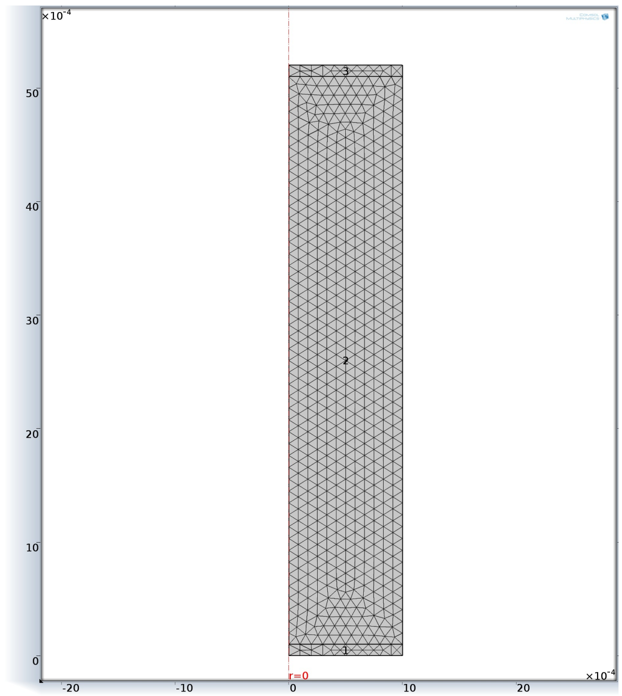

Figure 3: Meshing of the geometry.

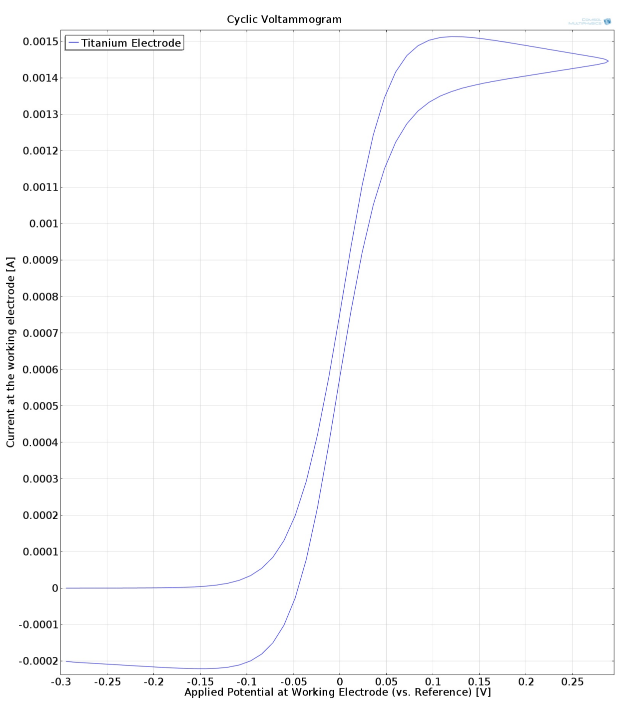

Figure 4: Cyclic voltammogram for Titanium electrode material.