Electric Field Density Distribution for Cochlear Implant Electrodes

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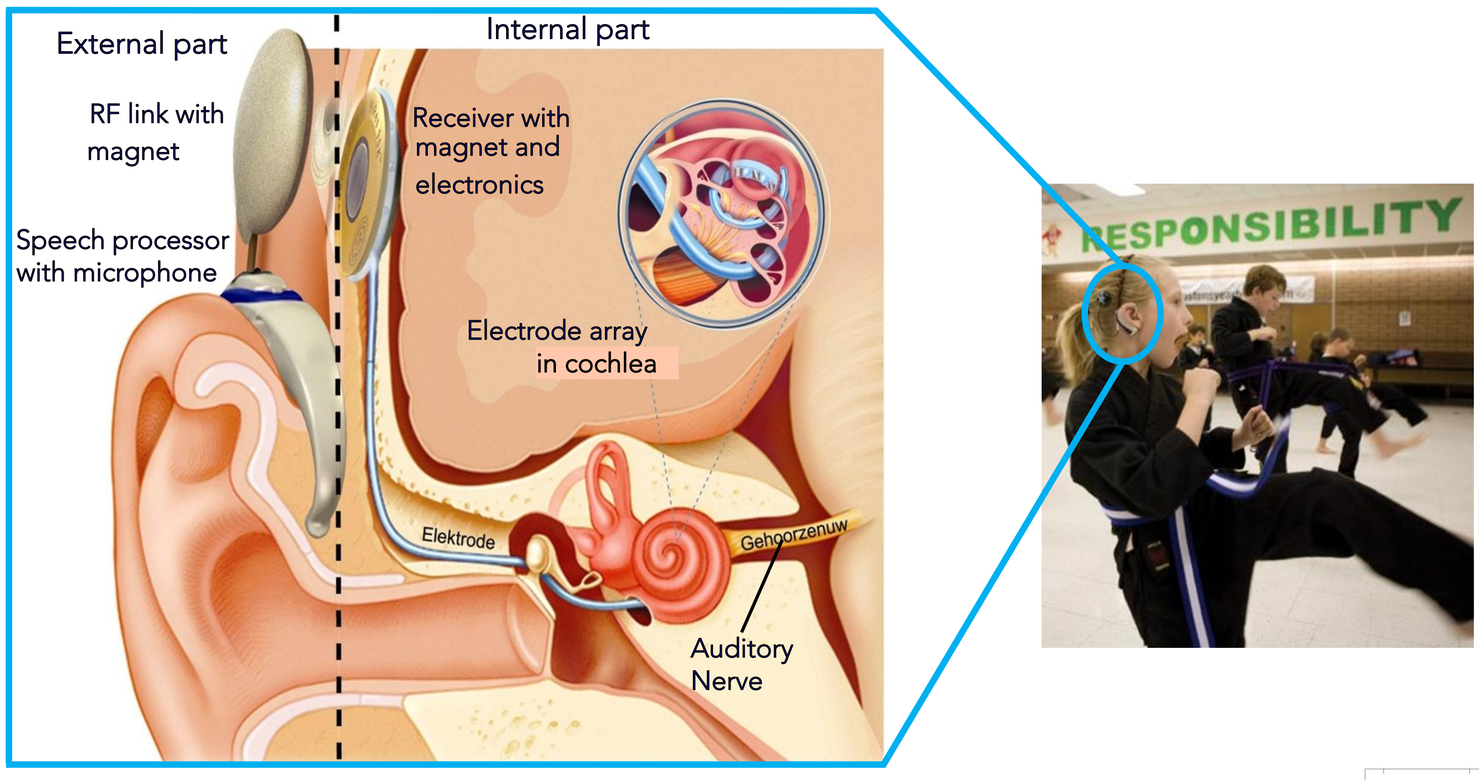


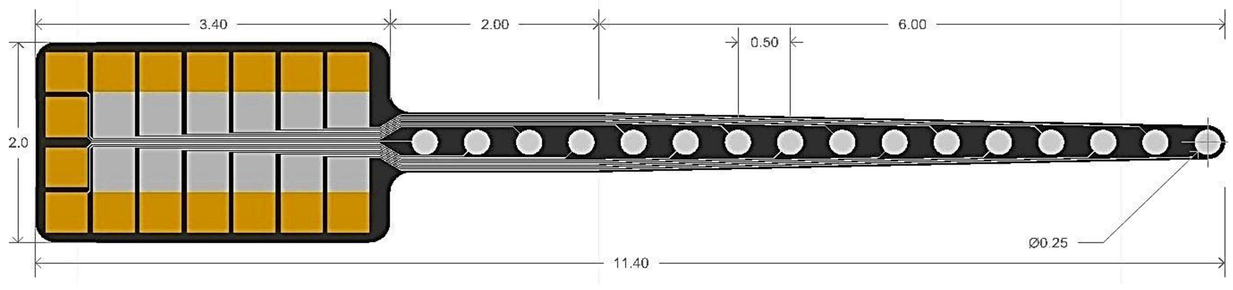
Figure 1: Sketch of a human ear with the implant

Introduction:

Cochlear Implants (CIs) are implantable devices that bypass the non-functional inner ear and directly stimulate the auditory nerve with electric currents, thus enabling deaf people to experience sound again.

Geometry:

The basic design of CI electrode array consists of an Silicon substrate with titanium nitride (TiN) stimulation sites [1] coated with Parylene HT (Figure 2). Three different electrode configurations are proposed: Protruded, Planar and Embedded (Figure 3). The goal is to minimize the potential, but it has to be high enough to trigger an action potential. Figure 4 shows the non-scaled geometry of the model.



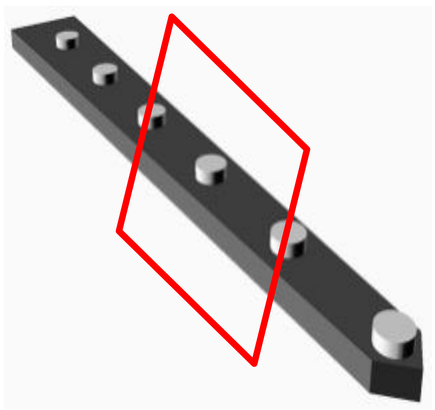
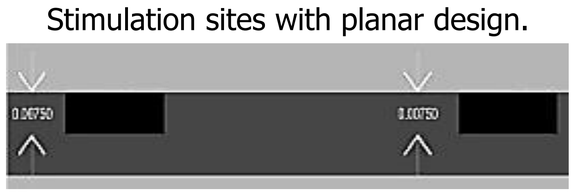


Figure 2: Design of the stiff probe

Titanium Nitride Electrodes
Silicon Base
Parylene
Perilymph (Fluid in Cochlea)

Stimulation sites with protruded design.

Stimulation sites with planar design.



Stimulation sites with embedded design.

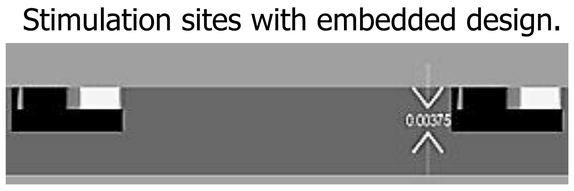


Figure 3: The three proposed configurations

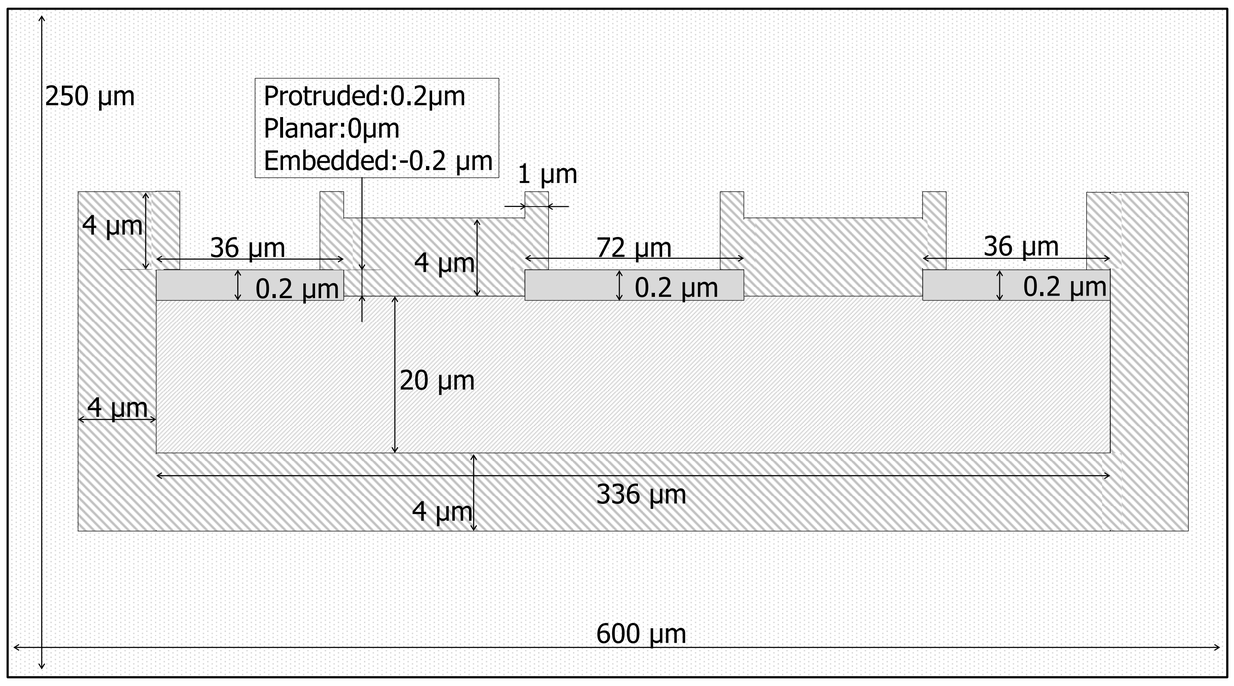


Figure 4: Geometry of the simulated model of a cross-section of an electrode array (the red parallelogram of Figure 2) inside a cochlea. The cochlea is considered as a rectangle here [2].

Results:

The AC/DC module from Comsol 4.2a has been used with a parametric sweep to switch between the different configurations. The center electrode is stimulated with a potential of 544 mV [4] and the bottom boundary is considered as a ground. The fluid in the cochlea is Perilymph, a fluid with high K^+ and low Na^+ concentration [3]. A cut line is taken at 30 µm from the surface of the substrate along the x-axis.

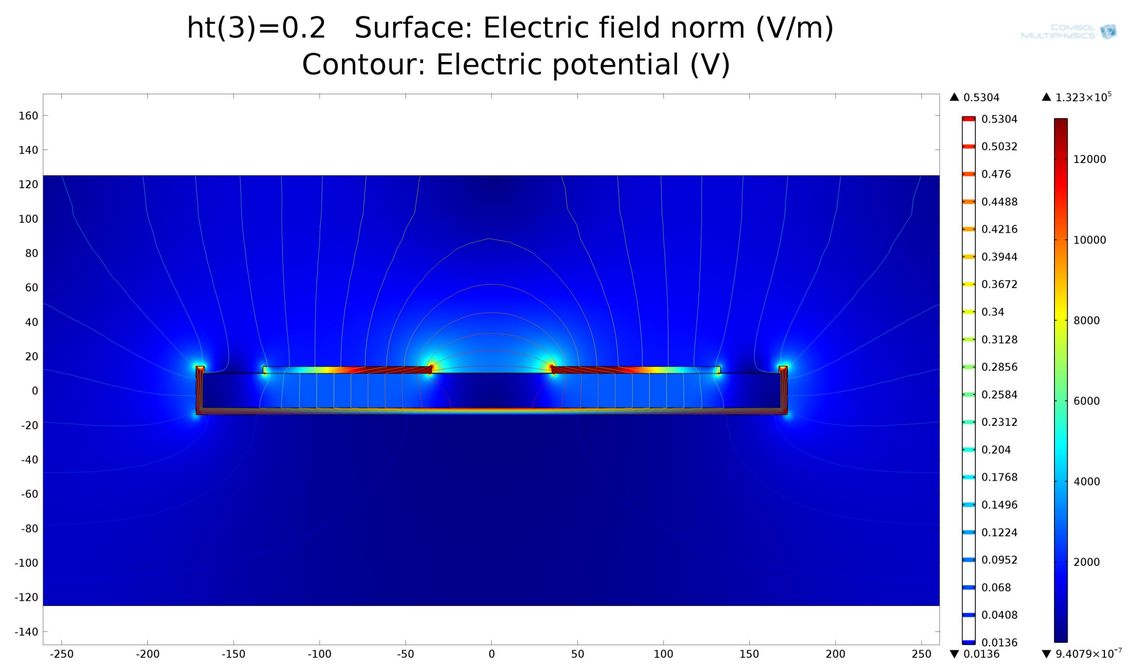


Figure 5: Electric Field Distribution of the model for the Protruded design

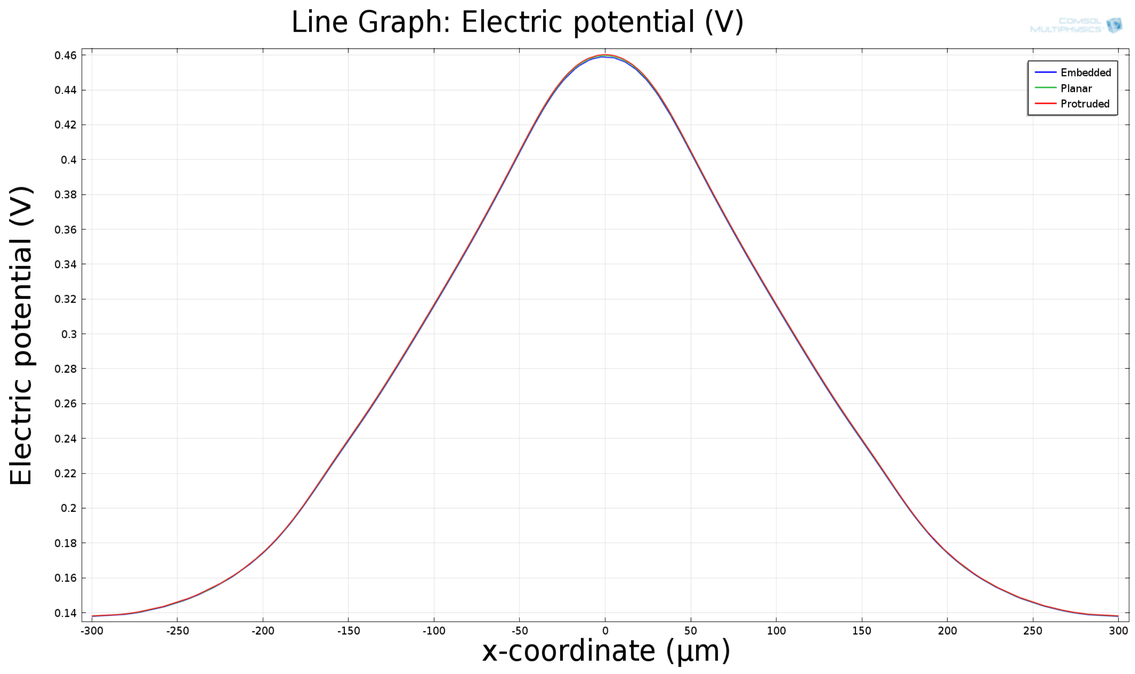


Figure 6: Potential at 30 µm from the surface for the three different designs

Conclusions:

Because of the little difference in shape of the electric field distribution (Figure 6), the protruded design has been chosen from fabrication point of view.

References:

[1] N. S. Lawand, P. J. French, J. J. Briaire, J. H. M Frijns, "Silicon probes for cochlear auditory nerve stimulation and measurement," Advanced Materials Research, Vol. 254, pp. 82 – 85, (2011).

[2] Clark, G. (2003). Cochlear Implants, Fundamentals and Applications. Melbourne: Springer Science+Business Media, Inc.

[3] Rienen, U. v., Flehr, J., Schreiber, U., Schulze, S., Gimsa, U., Baumann, W., et al. (2005). Electro-Quasistatic Simulations in Bio-Systems Engineering and Medical Engineering. Advances in Radio Science 3, 39-49.

[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.

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