Electric Field Density Distribution for Cochlear Implant Electrodes

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Enabling new technology

BIONICS

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Contents

- Cochlear Implant history, basics & problems
- Silicon electrode design
- Comsol 4.2 a ® Simulations
- Simulation results
- Conclusion and Future Work

History

1855 - Ear trumpet

1930 – Vacuum tube

1953 – Transistor

1994 – In-Ear

1984 – Cochlear Implant

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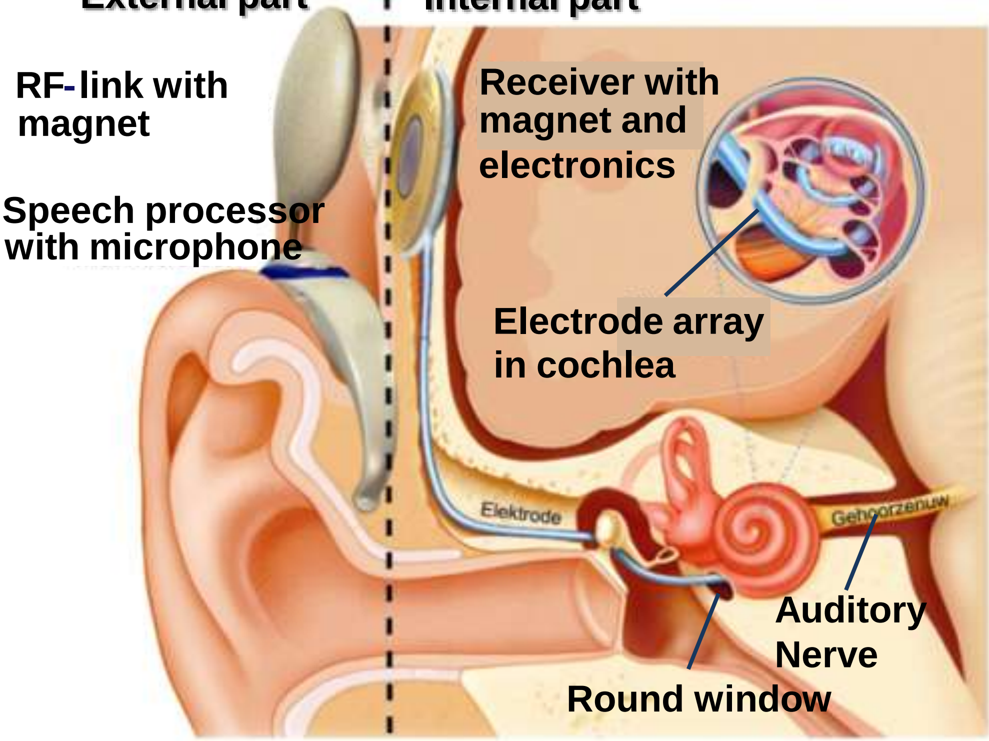
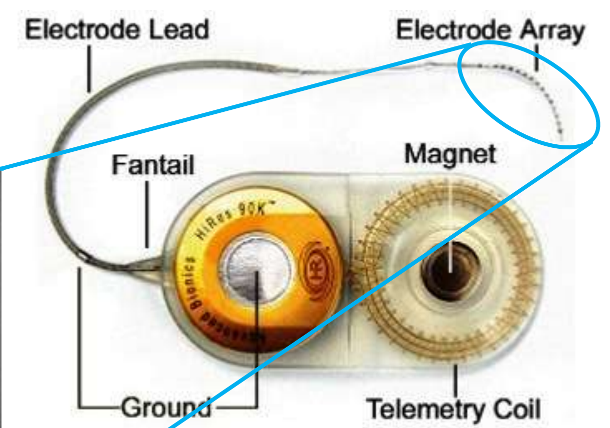
Cochlear Implant (CI) & problems



- To reduce size and power consumption
- To prevent electrode breakage and tissue damage during insertion.
- Cocktail party effect.
- Delivery of more sound details to the current electrodes.
- Appreciate music.
- To reduce surgery & manufacturing cost



Details of CI with a closer view of the electrode array

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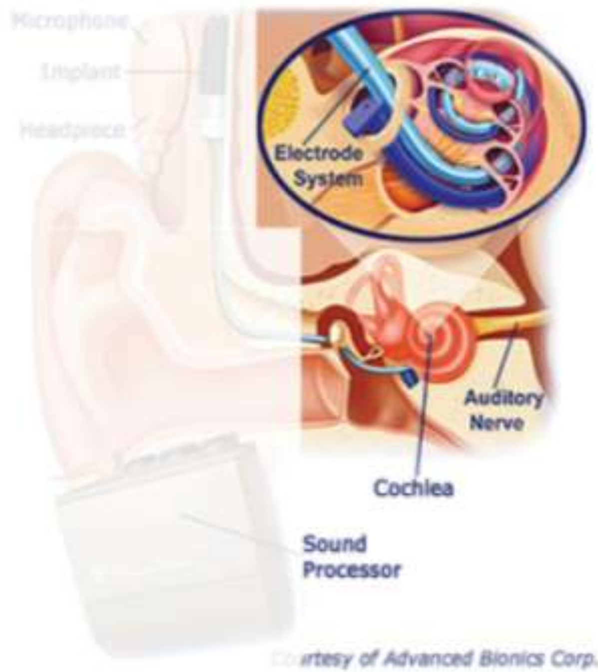
Framework of Smac-*it* project

Electrode design and fabrication



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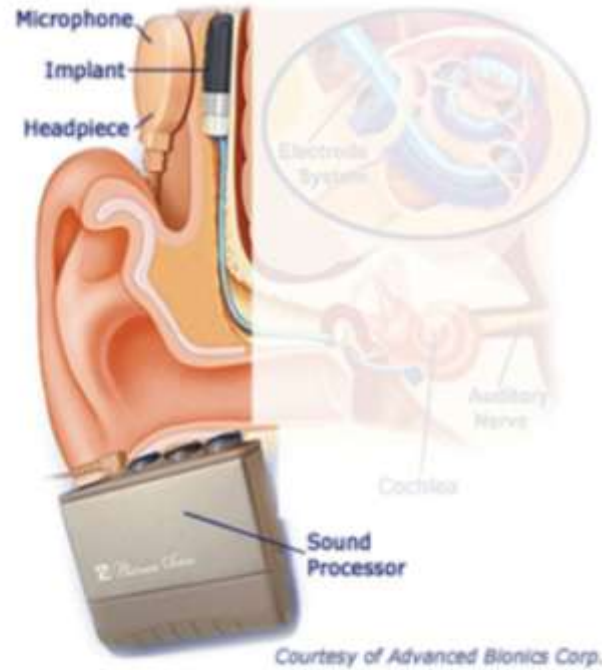
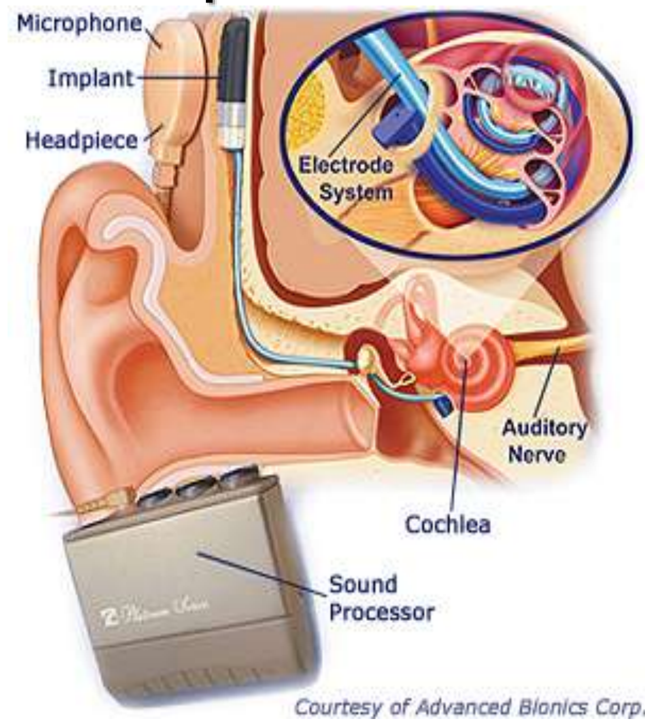
Joost van Driel
Supervisors : Prof. Dr. P J. French
Prof. Dr. ir. J H M. Frijns

Low power electronics and low level integration



Wannaya Ngamkham
Supervisor : Dr. ir. W A. Serdijn

Complete System level Optimizations



Ghazaleh Nazarian
Supervisor: Dr. G N. Gaydadjiev

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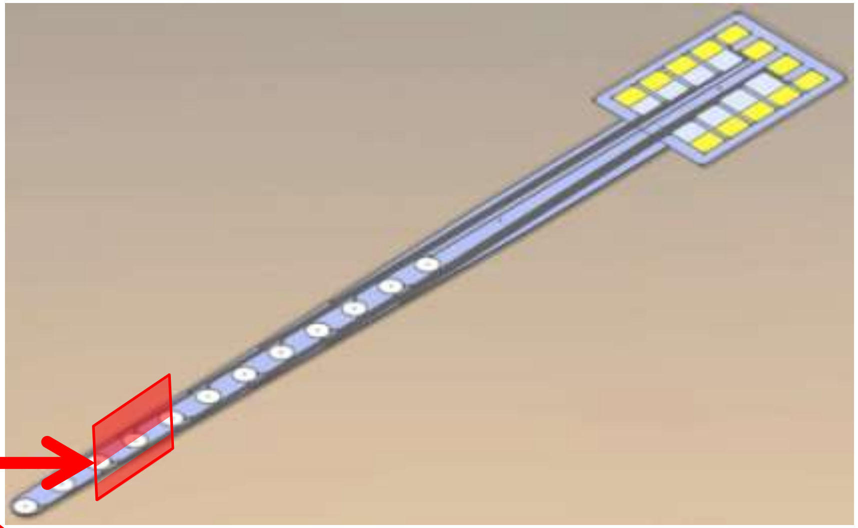
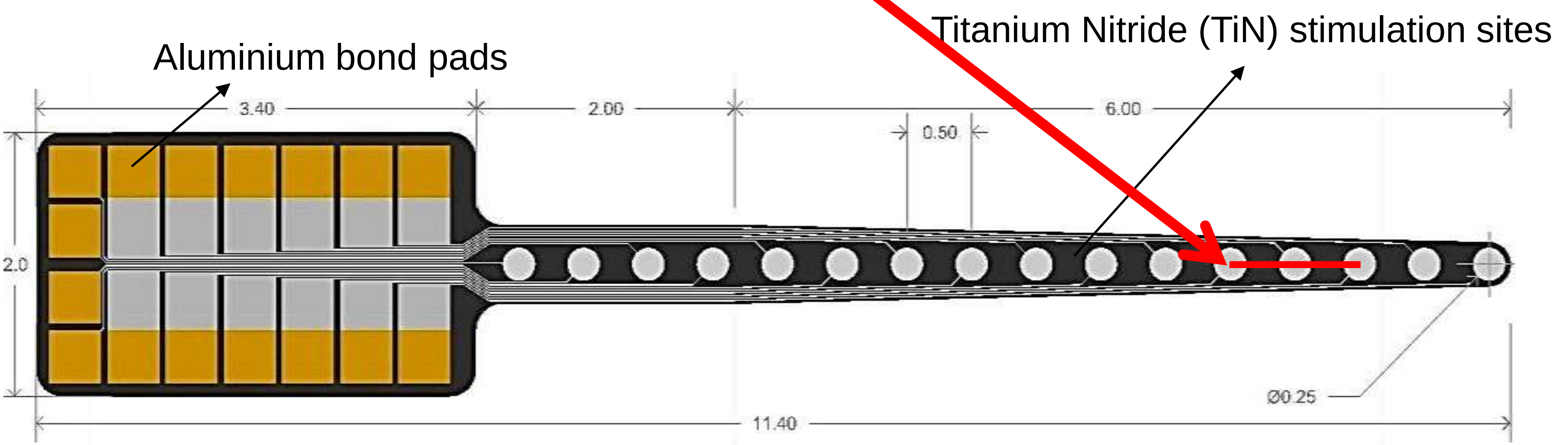
Electrode design

- TiN stimulation sites: 16
- Diameter of TiN site: 72 µm
- Distance between 2 sites: 150 µm
- Aimed thickness of TiN site: 200 nm

- Cross-section





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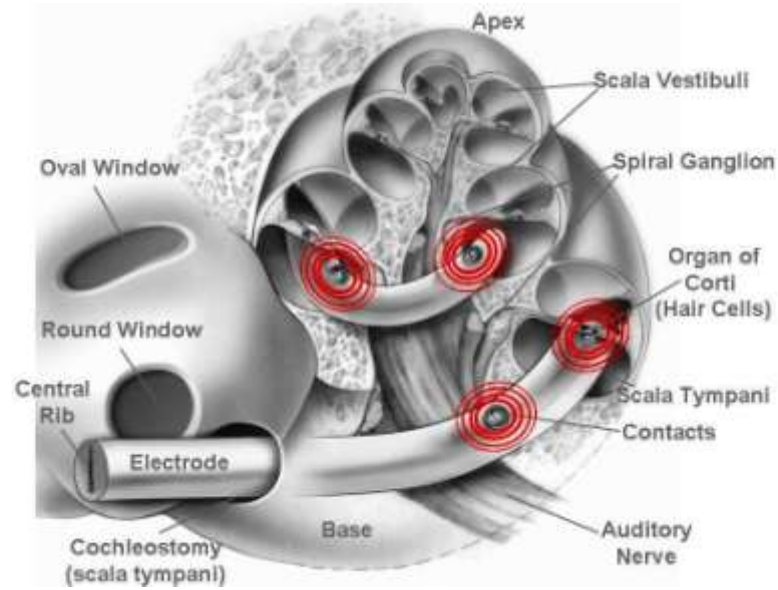
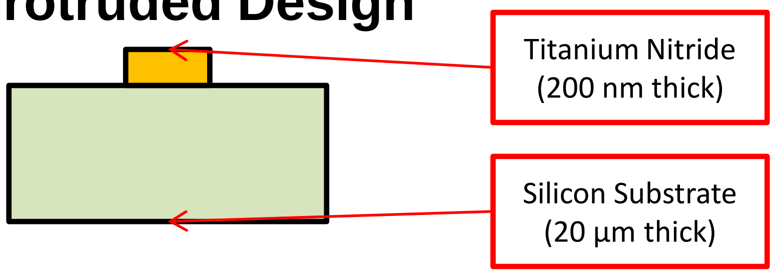
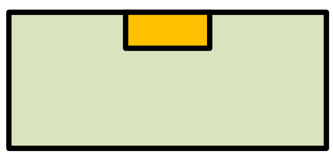
Simulations (1)



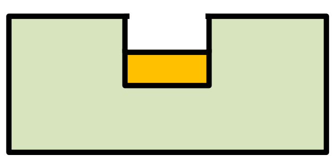
- **Electric Field Distribution Evaluation**
- **Cross Section (2D)**
- **Protruded Design**

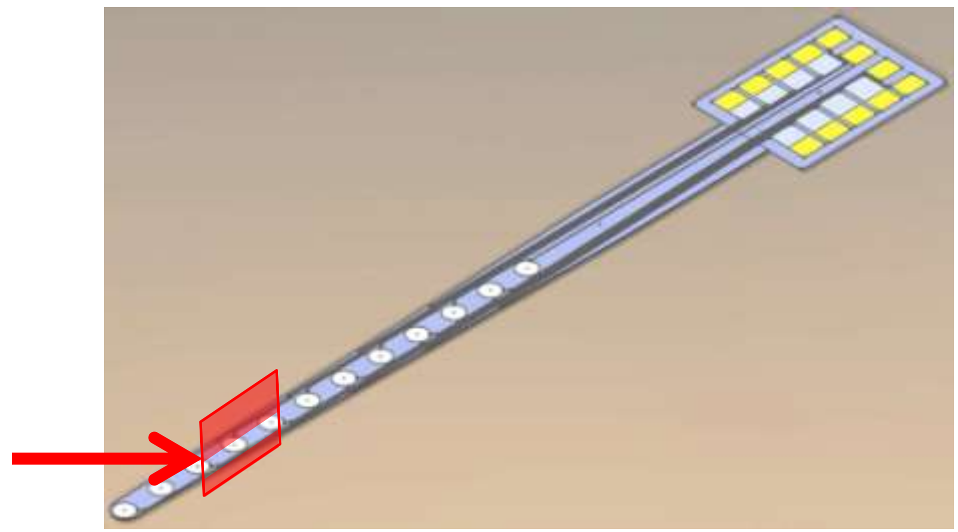


- **Planar Design**

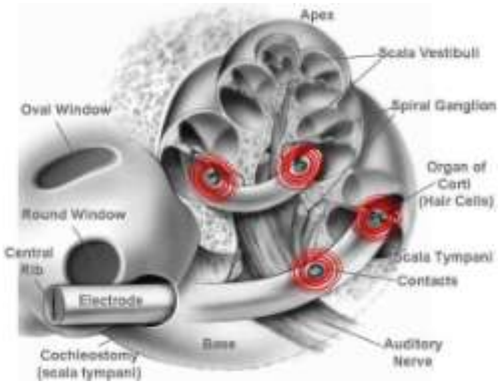


- **Embedded Design**

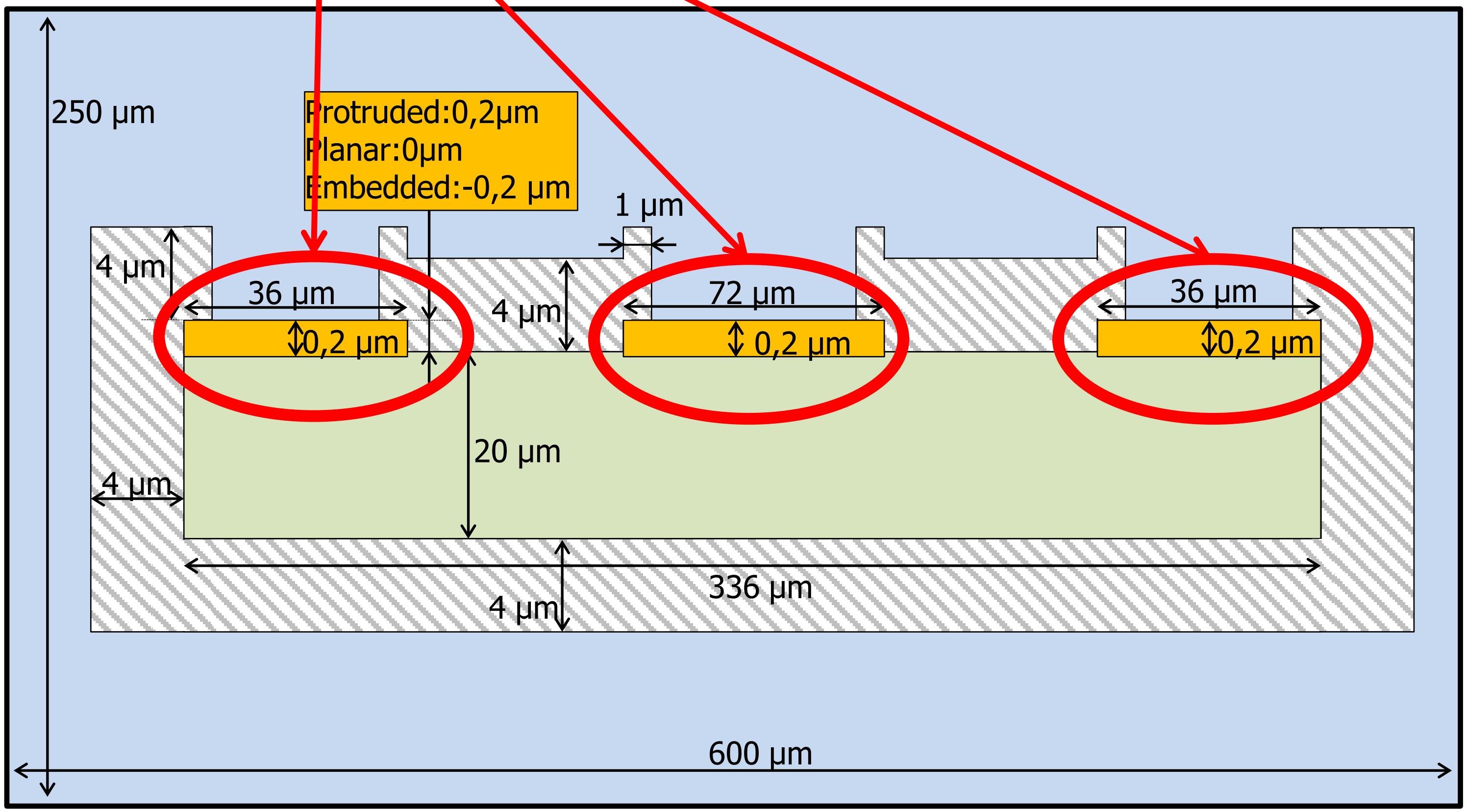




Simulations (2)



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



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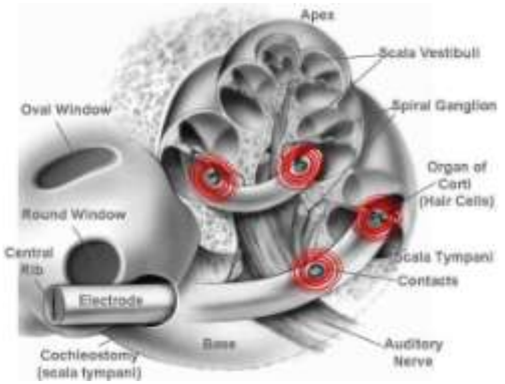
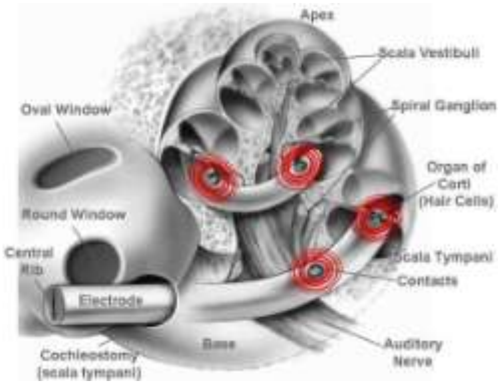
Simulations (3)

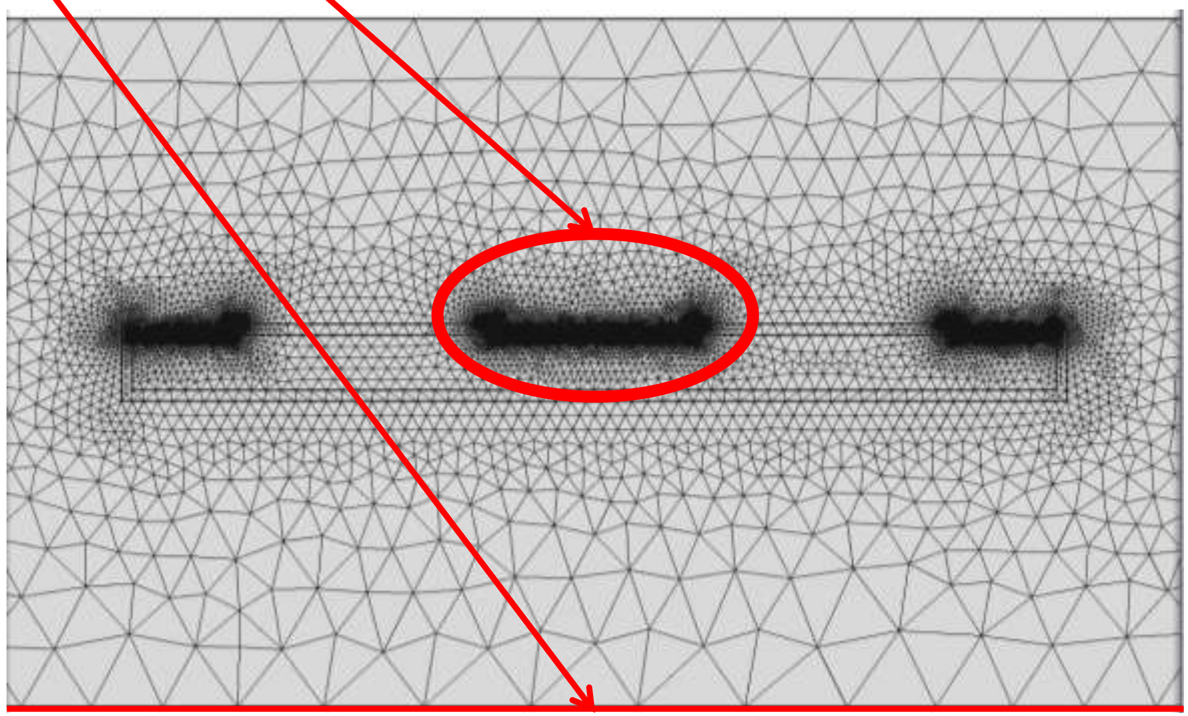


Name	Electrical Conductivity, sigma (S/m)	Relative Permittivity, ε_r
Titanium Nitride	5000	100
Silicon	4.3e-4	11.7
Perilymph	2	50
Parylene HT	5e-20	2.2

Simulations (4)



- **Comsol 4.2 - AC/DC Module**
    - ***Electric Currents***
- **544 mV on centre electrode**
- **Bottom boundary of Perilymph: Ground**
- **Parametric Sweep for different designs**



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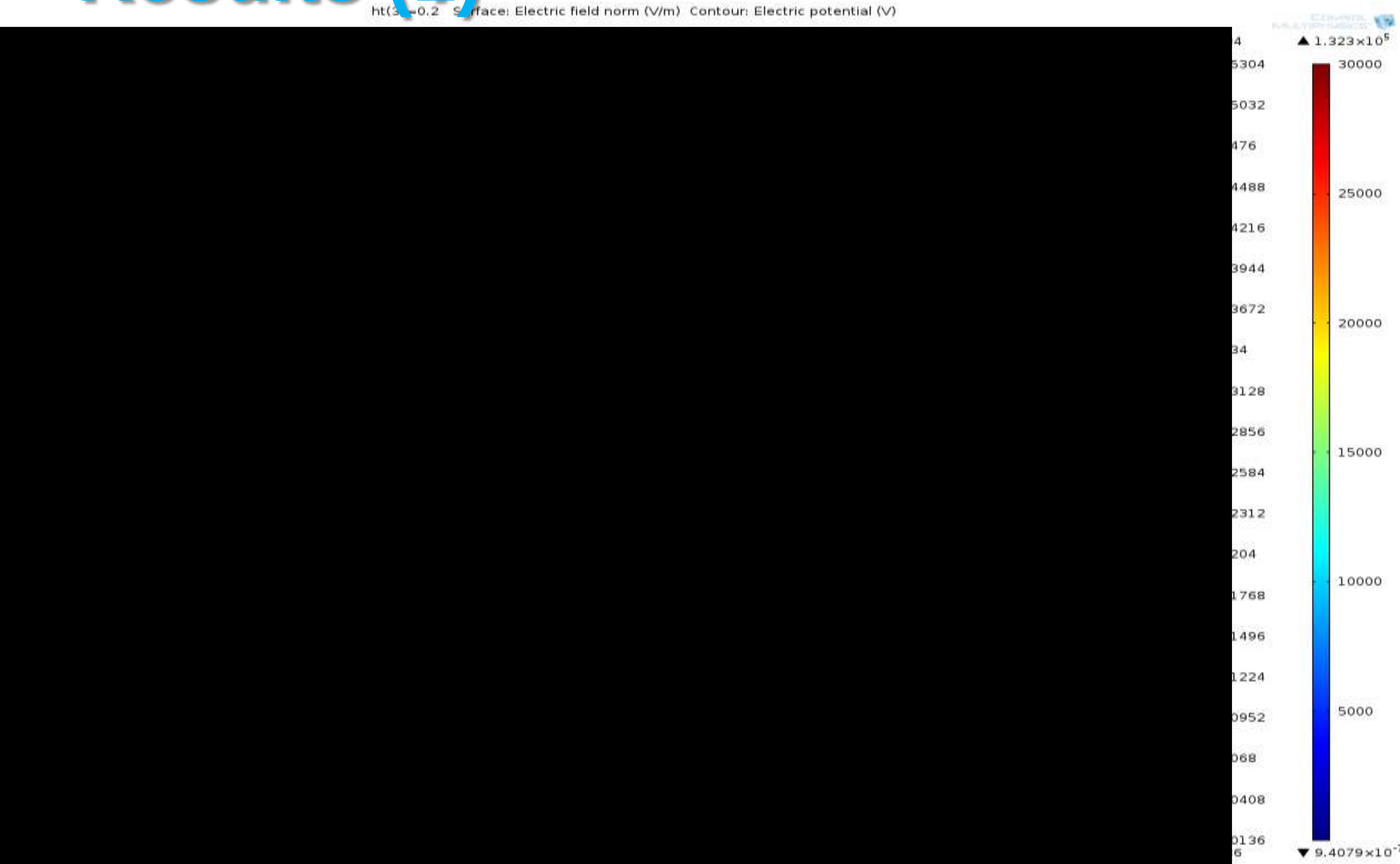
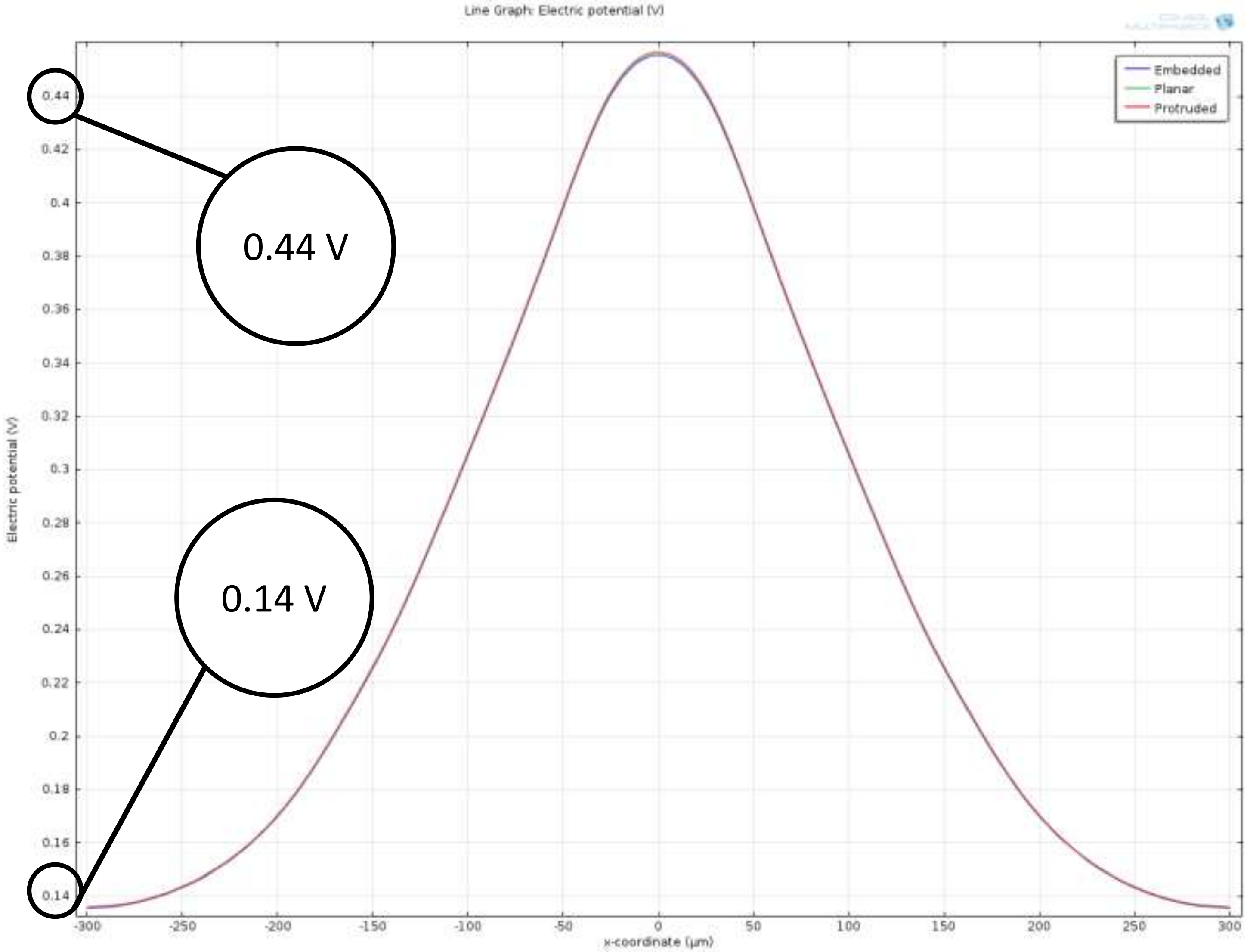
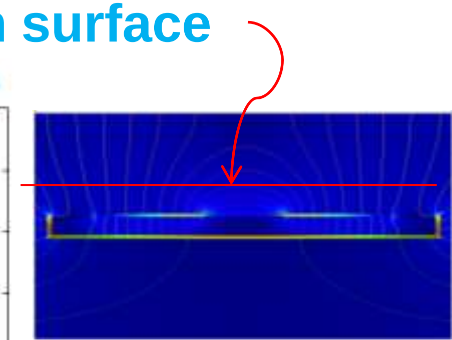
Results (1)


Electric field norm (V/m)
Contour: Electric potential (V)
▲ 1.323×10^{5}
30000
25000
20000
15000
10000
5000
▼ 9.4079×10^{-7}

Results (2)

Potential at 30 µm from surface





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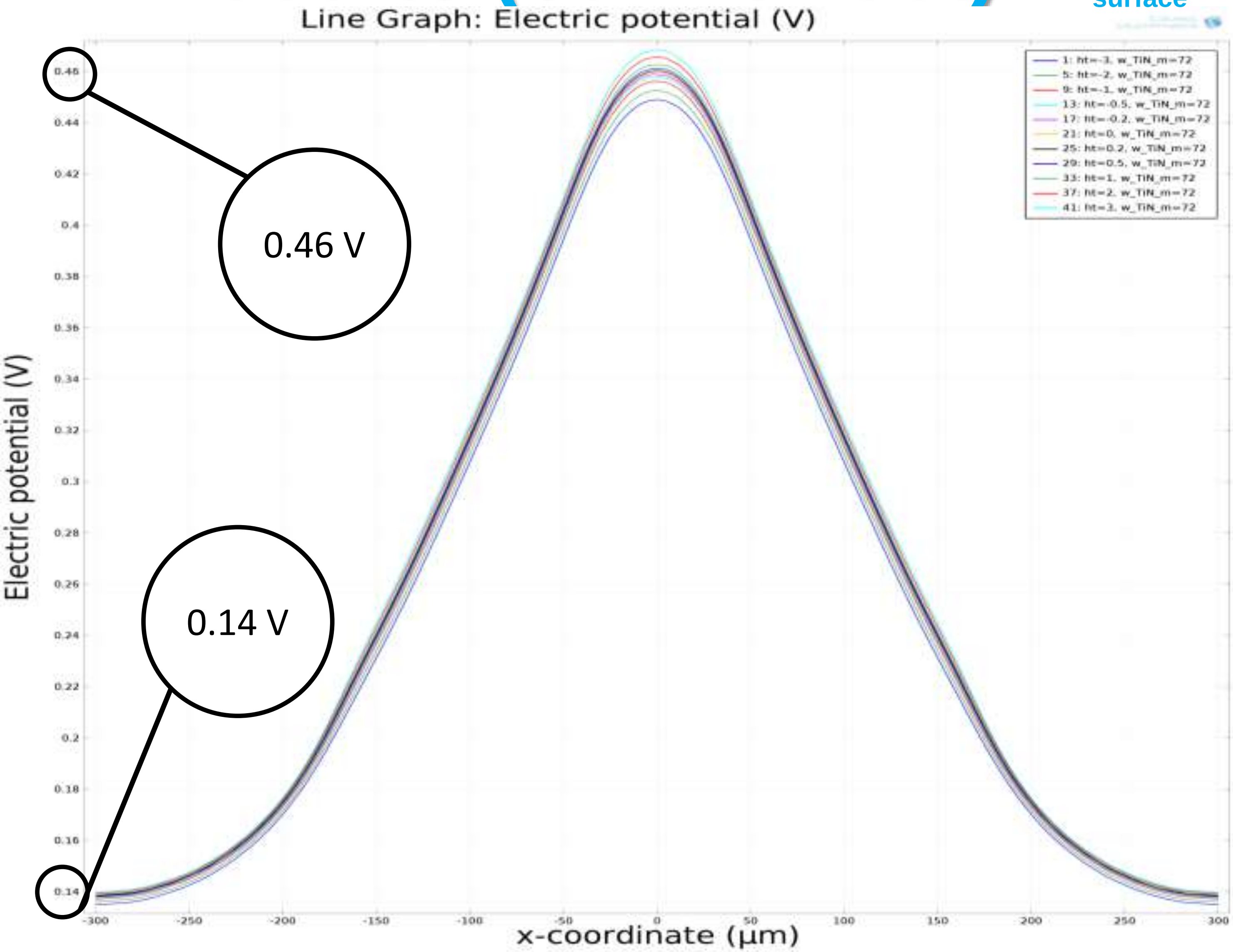
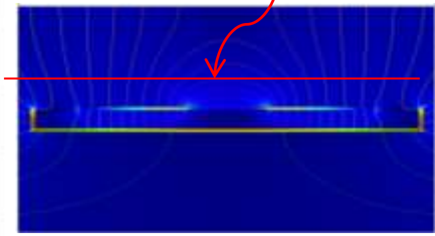
Results (3um offset)



Potential at 30 µm from surface



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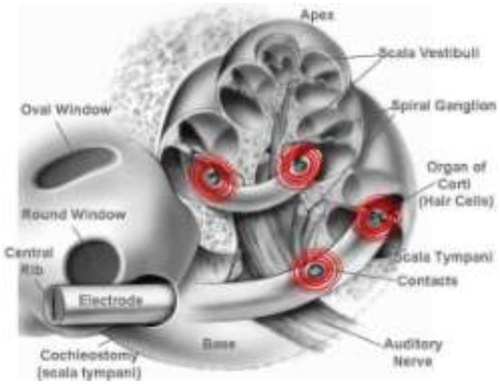
Conclusions



- **Negligible difference between 3 designs**
- **Choice depends on fabrication**
  - ***Protruded***

Future Work

- **Characterization of materials**
  - ***Biocompatibility***
  - ***Maximum Current Density***
- **Creating flexible devices**
- **Increasing the amount of electrodes**
- **Embedding electronics**
- **Insertion techniques**

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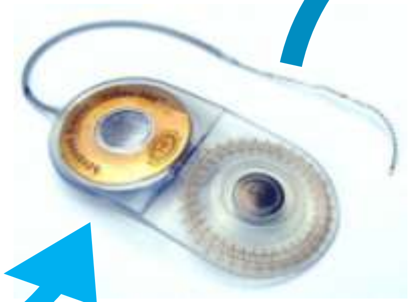
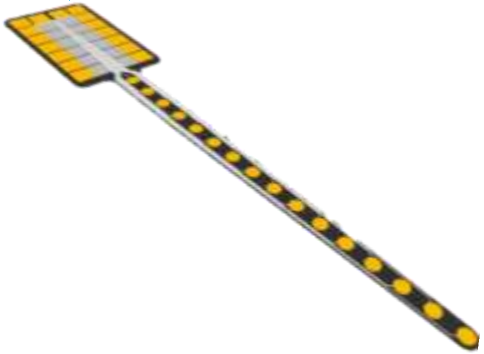
Thank you.

Electrode array Development.





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1: Electronic Instrumentation Laboratory (EI Lab), Delft University of Technology
2: Department of ORL-HNS, Leiden University Medical Center

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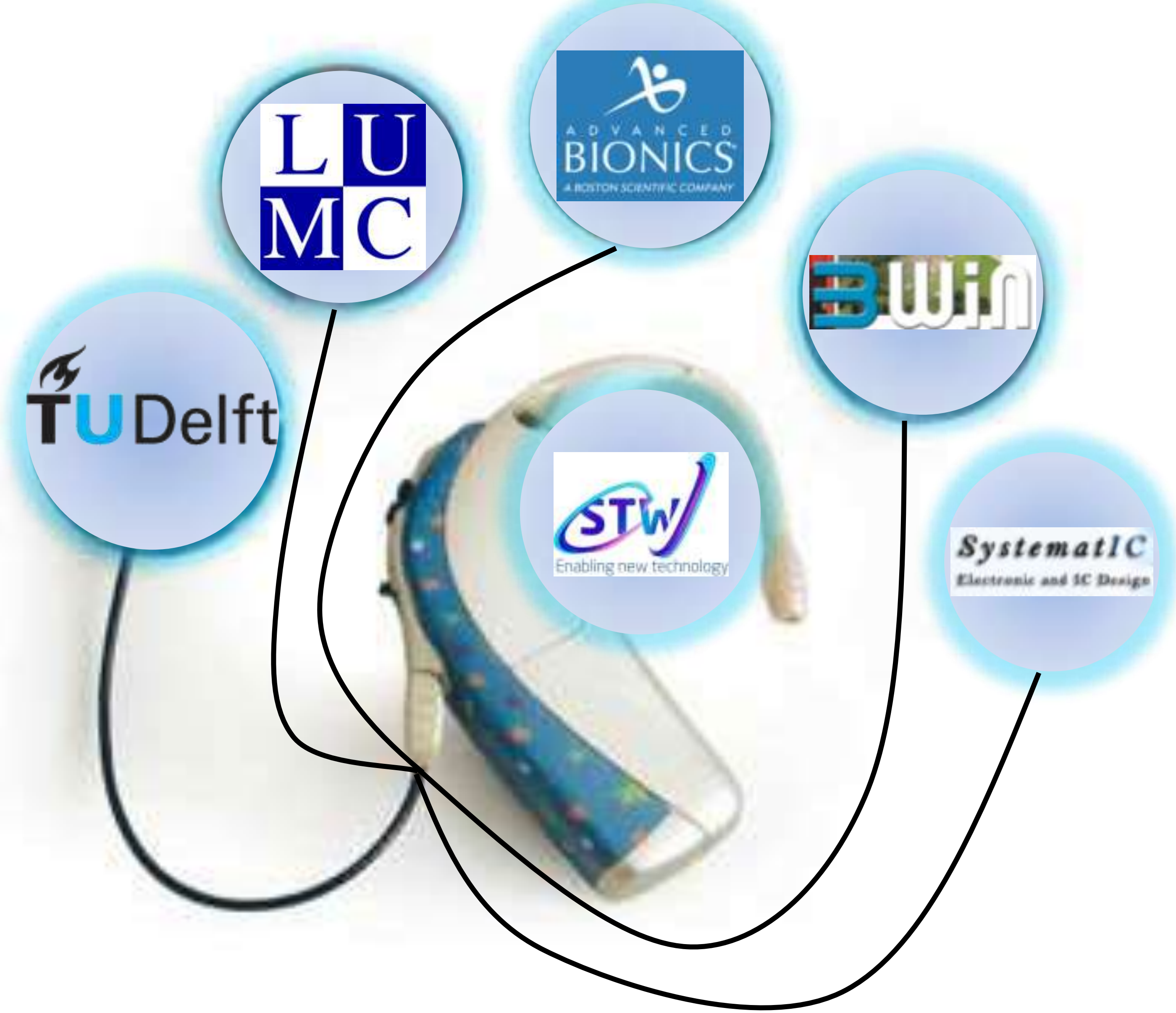
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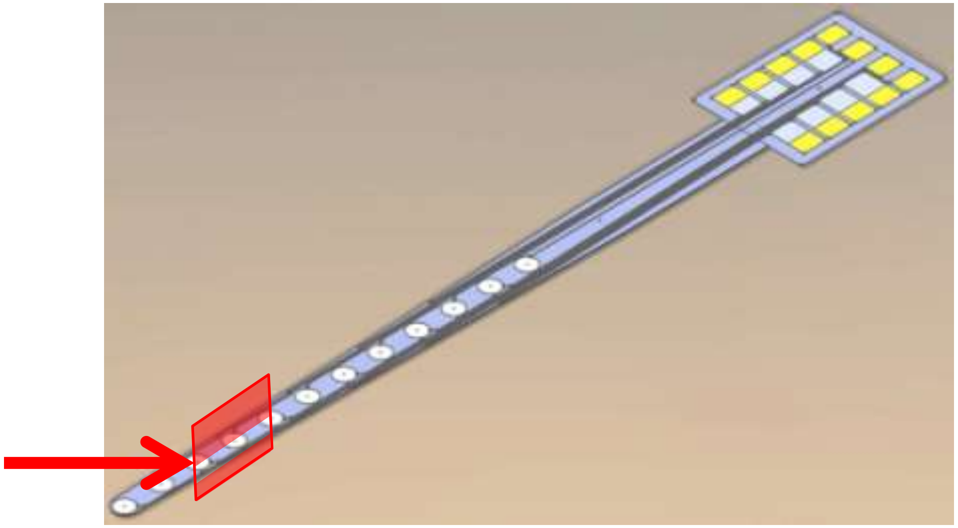
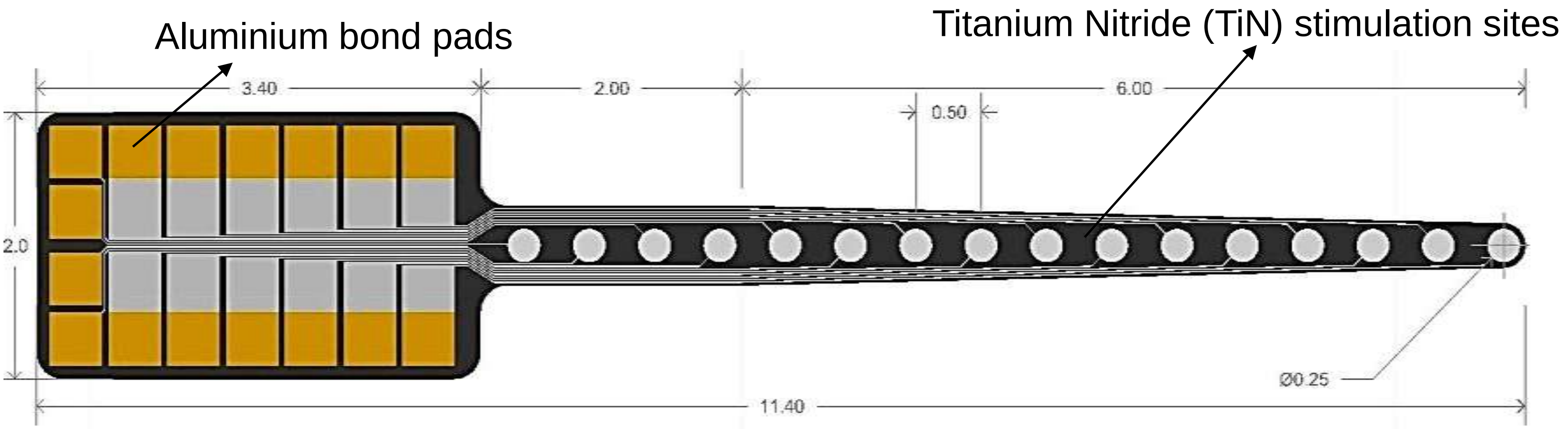
Electronic and IC Design

Electrode design

- TiN stimulation sites: 16
- Diameter of TiN site: 72 µm
- Distance between 2 sites: 150 µm
- Aimed thickness of TiN site: 200 nm
- Width of metal line: 4 µm
- Distance between 2 metal lines: 5 µm
- Bond pad size: 130 x 130 µm





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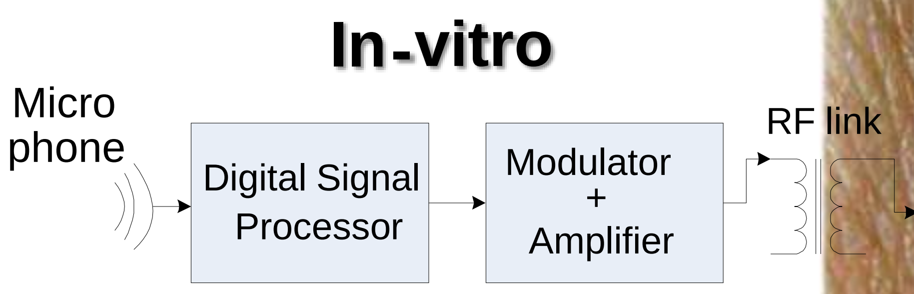
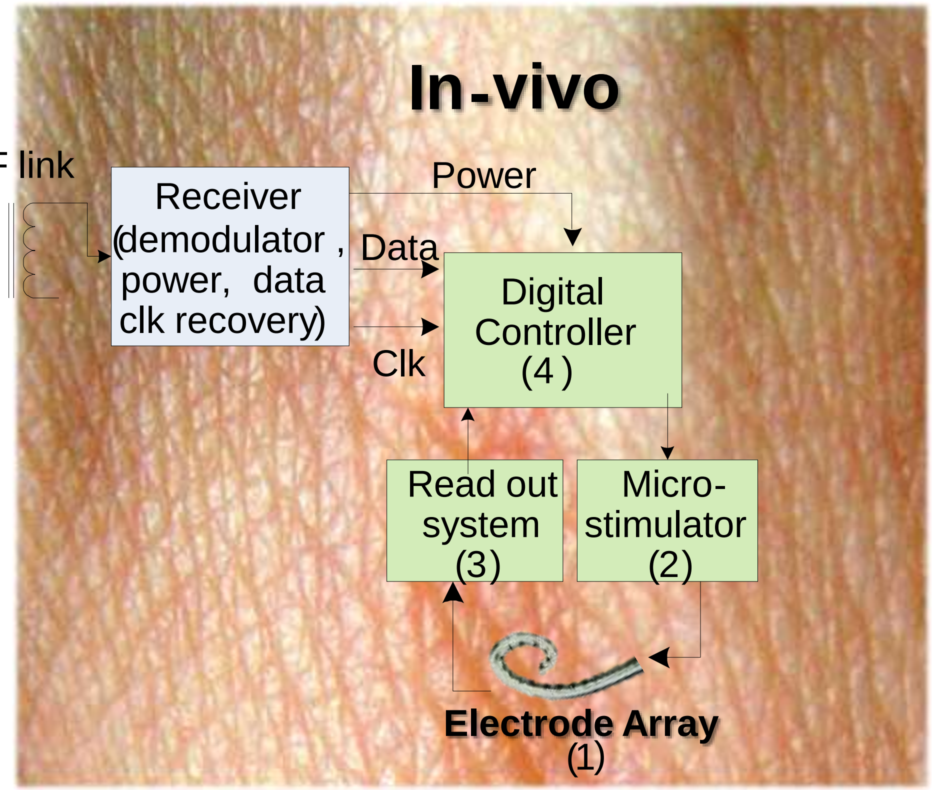
Block diagram of a modern cochlear implant (CI)





Modules under research

1 **Electrode Array**

2 Micro - stimulator

3 Read out system

4 Digital controller (Microprocessor + Compiler)

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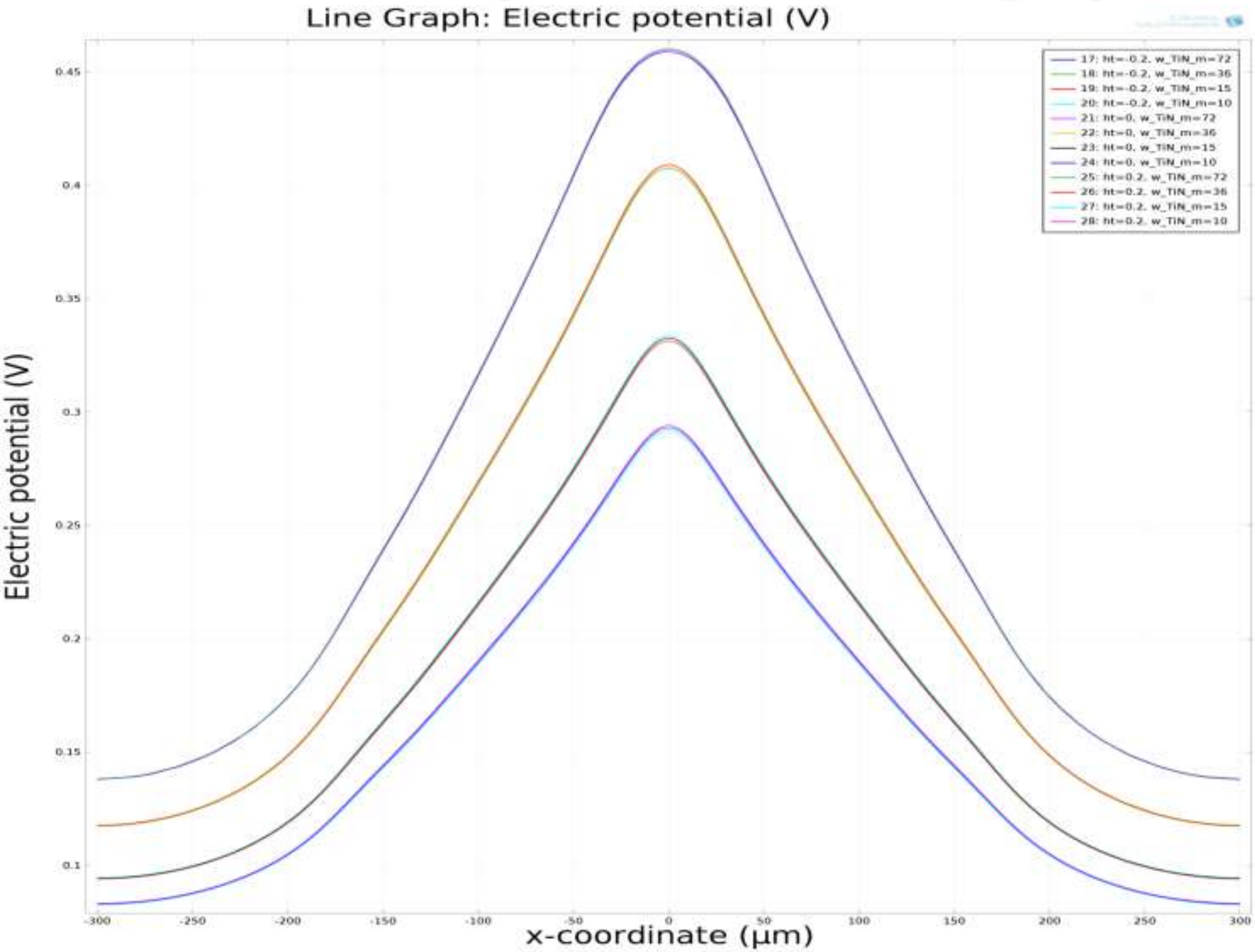
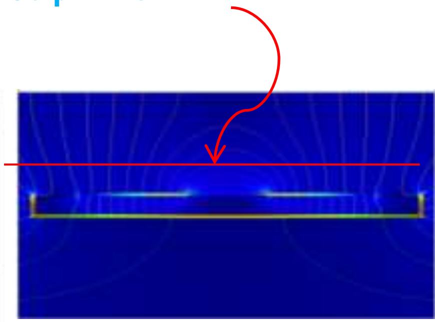
Publications

- N. S. Lawand, P. J. French, J. J. Briaire, J. H. M. Frijns: Study of fabrication strategies for Silicon in Cochlear Implants, Proc. SAFE 2009, pp. 28-31, November, 2009.
- N. S. Lawand, P. J. French, J. J. Briaire, J. H. M. Frijns: Silicon Probes for Cochlear Auditory Nerve Stimulation and Measurement, Proc. International Conference on Materials for Advanced Technologies (ICMAT 2011), Advanced Materials Research Vol. 254, pp. 82-85, June-July 2011.
- N. S. Lawand, P. J. French, J. J. Briaire, J. H. M. Frijns: “Development of probes for cochlear implants”, IEEE Sensors, pp. 1827-1830, 2011.
- N. S. Lawand, P. J. French, J. J. Briaire, J. H. M. Frijns: Design and fabrication of silicon stiff probes: A step towards developed cochlear implant electrodes, Proc. Eurosensors XXV, Sept. 2011. (Invitation for extended special issue journal paper for Sensor & Actuators Invitation devoted to EUROSENSORS 2011 - Athens, Greece).
- N. S. Lawand, P. J. French, J. J. Briaire, J. H. M. Frijns: “Development of microelectrode material for nerve stimulation using TiN”, Proc. International conference on Materials and Applications for Sensors and Transducers, Budapest, Hungary, May 24-28, 2012 (Best presentation award).
- N. S. Lawand, P. J. French, J. J. Briaire, J. H. M. Frijns: “Cochlear Implant electrode improvement for long term implants”, 34th Annual International conference of the IEEE EMBS, San Diego, Aug 28-Sept 1, 2012.
- N. S. Lawand, P. J. French, J. J. Briaire, J. H. M. Frijns: “Thin TiN films deposited using DC magnetron sputtering for neural stimulation purposes”, Eurosensors XXVI, Krakow, Sept. 9-12, 2012.

Results (width change)

Potential at 30 µm from surface





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