Electrochemical Characterization of Implantable Biochips for Biosensing Application

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Synopsis

- Motivation
  - Trauma management in combat injury– *glucose and lactate sensing*
- Methodology
  - Using amperometry via Implantable Electrochemical cell on a chip for biosensing
- Focus
  - Design and characterize the working electrode using Microdisc electrode Array (MDEA) architecture for enhanced mass transport and sensitivity.
- Results
  - enhanced sensitivities due to radial diffusion

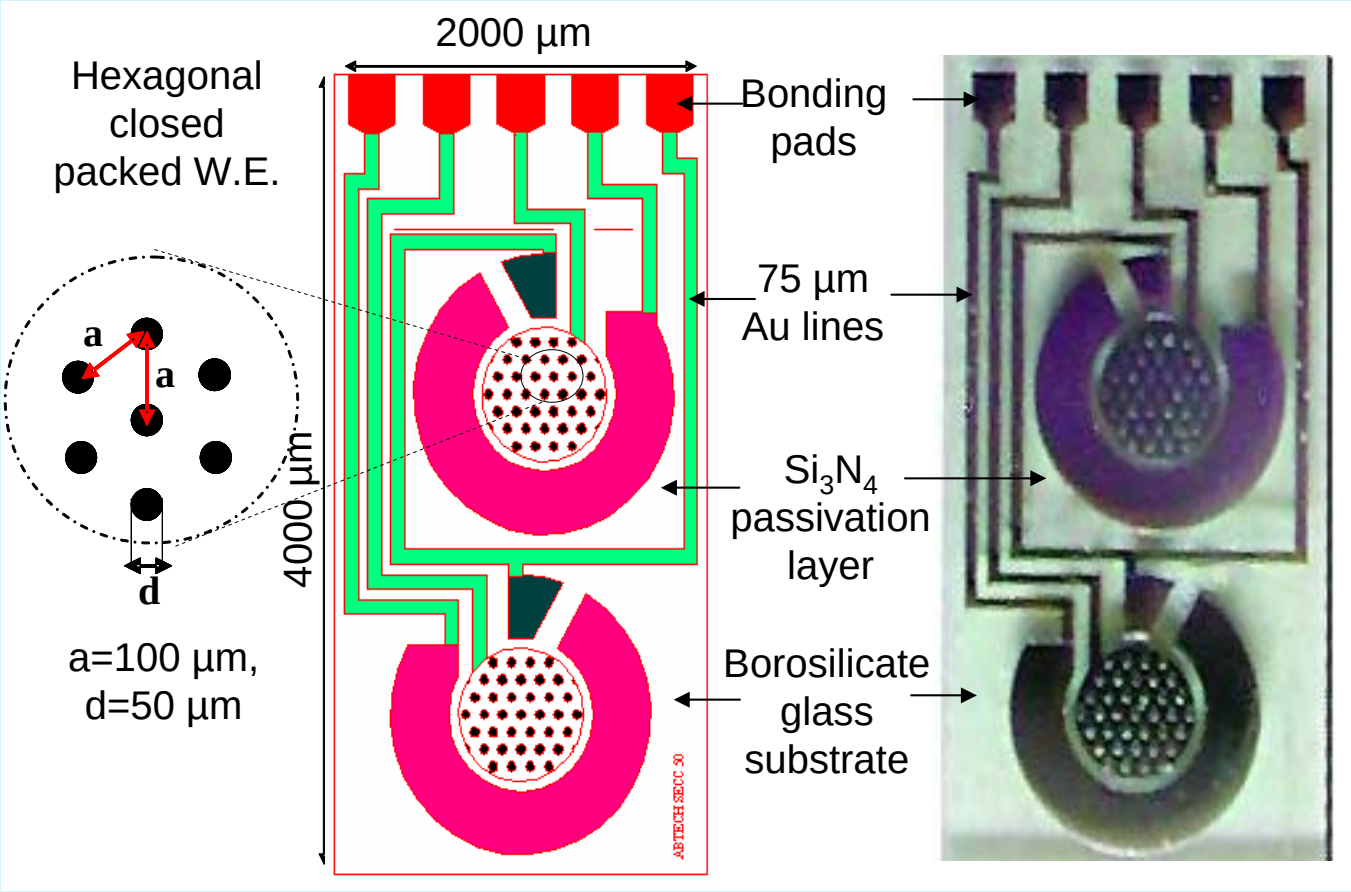
Importance of Glucose sensing to trauma

- *Hyperglycemia is associated with excess mortality in critically ill patients [1].*
- *Early hyperglycemia (glucose >=200 mg/dL) is associated with significantly higher infection and mortality rates in trauma patients independent of injury characteristics [1].*
- *Decreased blood flow to the muscles - vasoconstriction*
- *Decreased oxygen availability to the muscles*
- *Increased oxygen debt*
- *Increased lactic acid build up in the muscles*

Lactate is a surrogate for oxygen debt

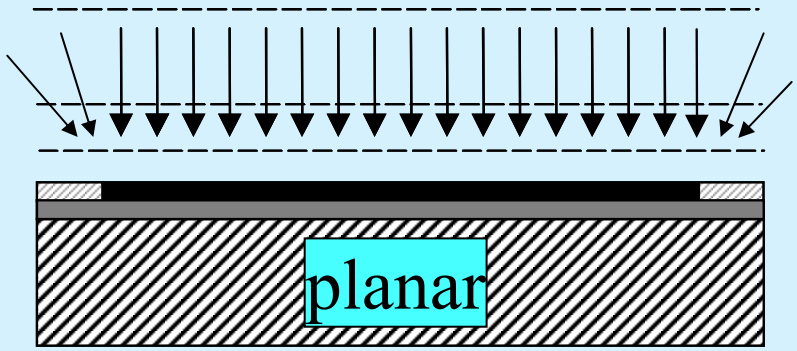
***1 Laird, Amanda M., Miller, Preston, et al.,* Relationship of Early Hyperglycemia to Mortality in Trauma Patients**, Journal of Trauma-Injury Infection & Critical Care. 56(5):1058-1062, May 2004.

Design of MDEA 5037 Electrochemical Cell chip

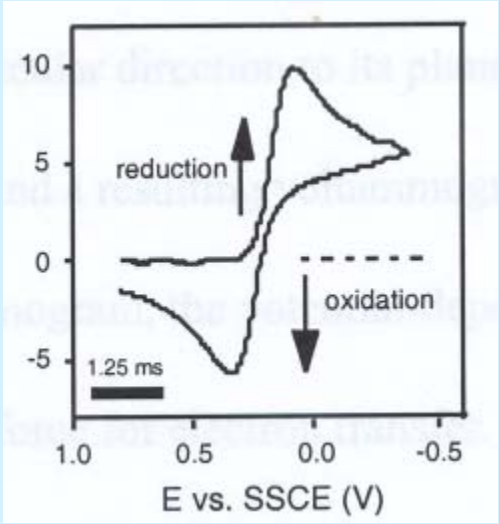


Radial vs. Semi-infinite Linear Diffusion

A

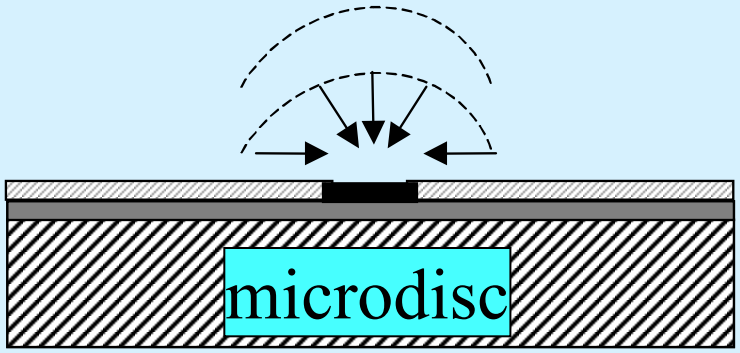


macroelectrodes

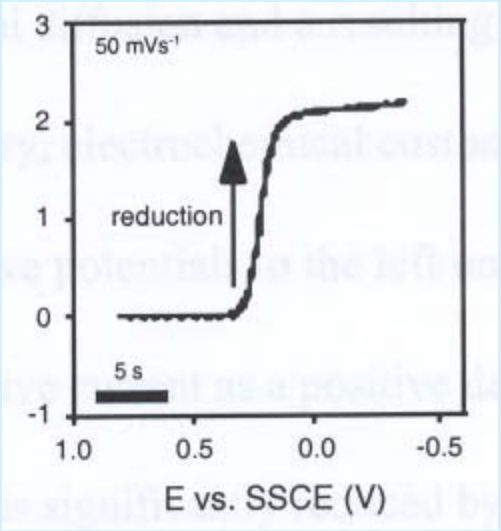


$$i_p = 2.686 \times 10^5 n^{3/2} C_{ox} D_{appt}^{1/2} v^{1/2} A$$

B

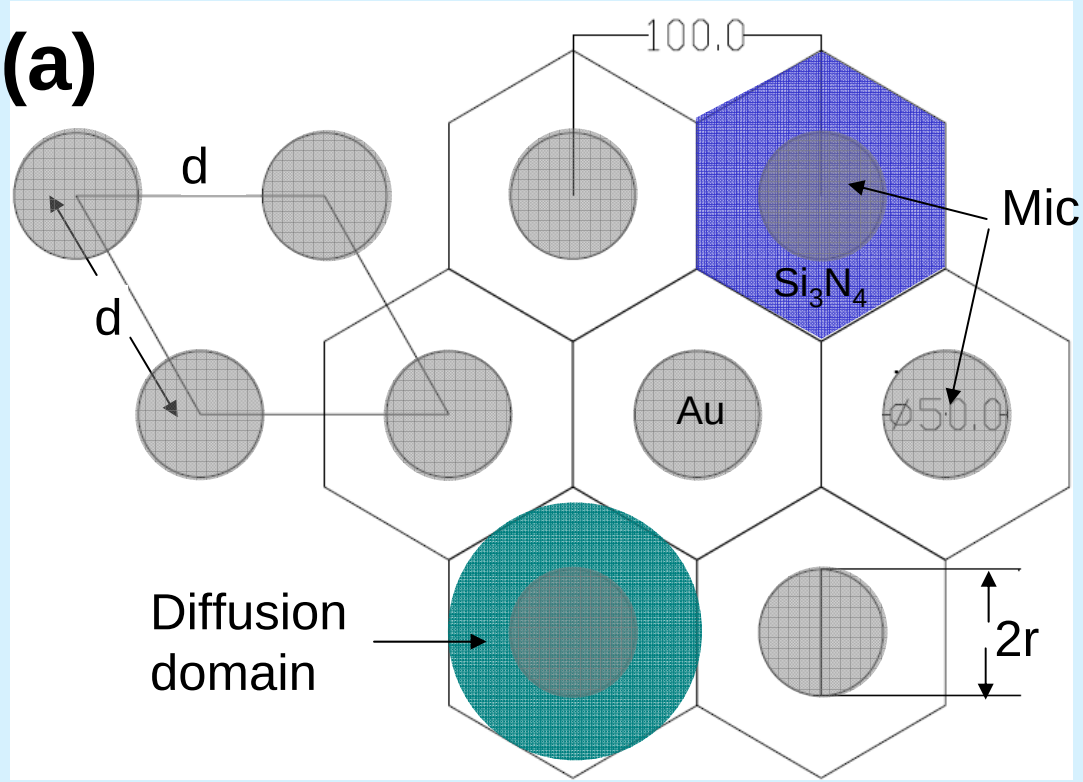


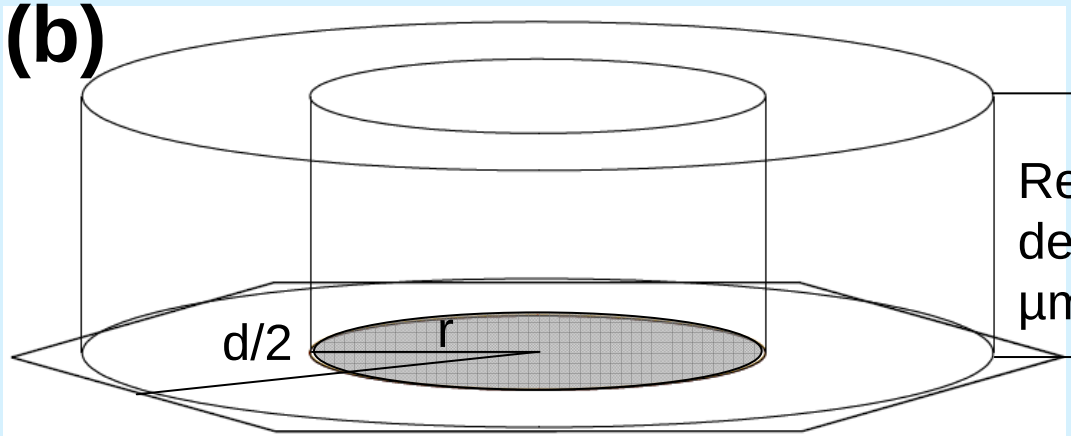
microelectrodes



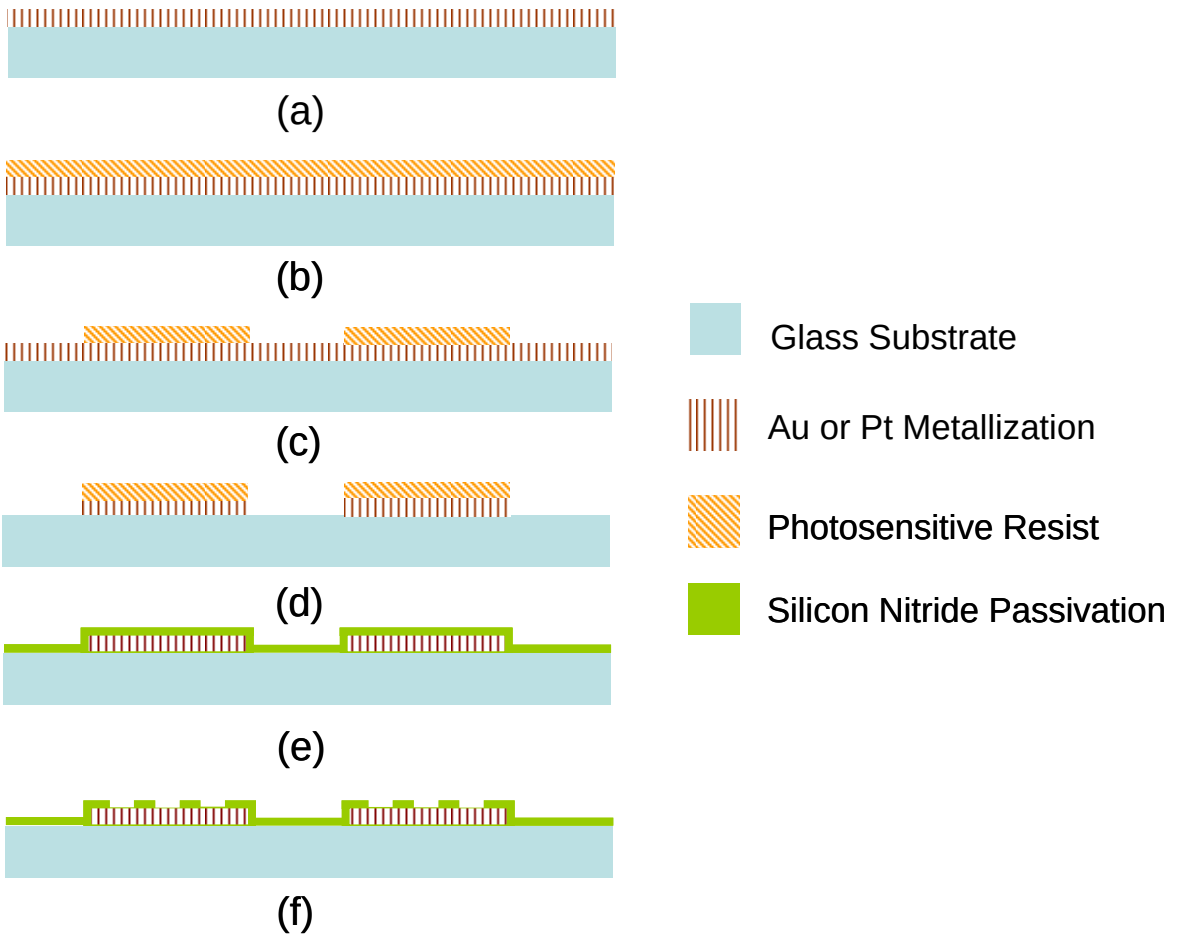
$$i_{ss} = \frac{8nFDC}{8L + \pi d}$$

Diffusion profile of Microdisc Electrode Arrays

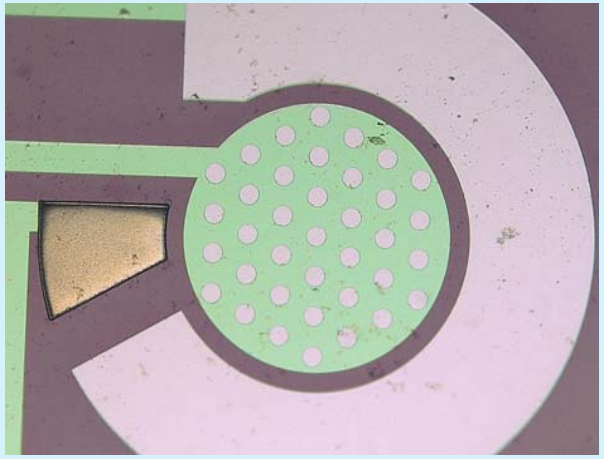


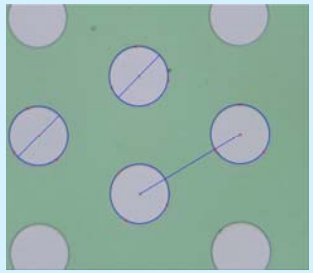


Fabrication of MDEAs

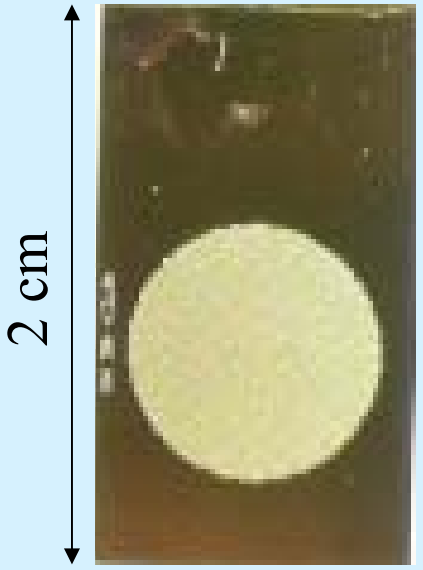


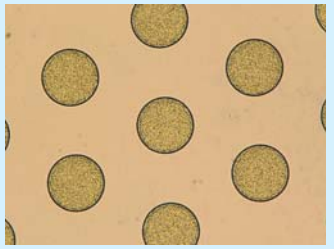
Fabricated MDEA 5037 and MDEA 050 electrodes



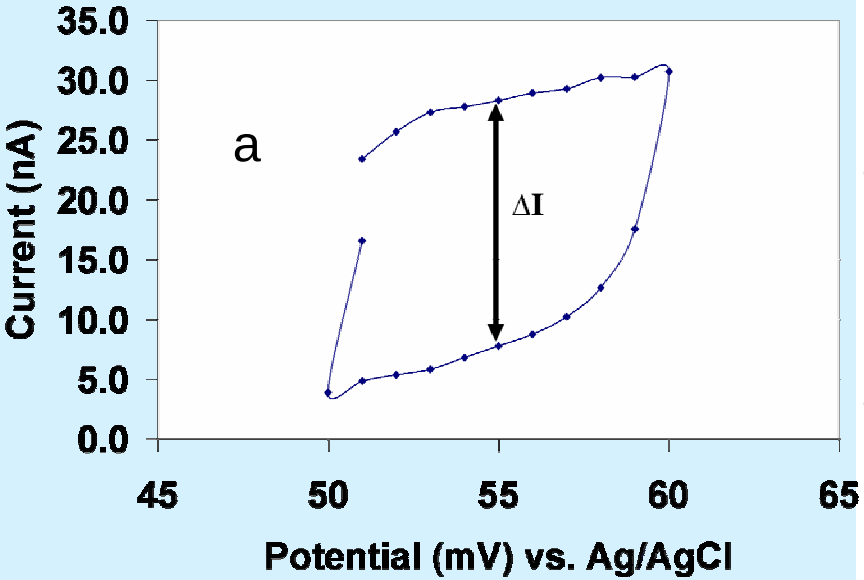


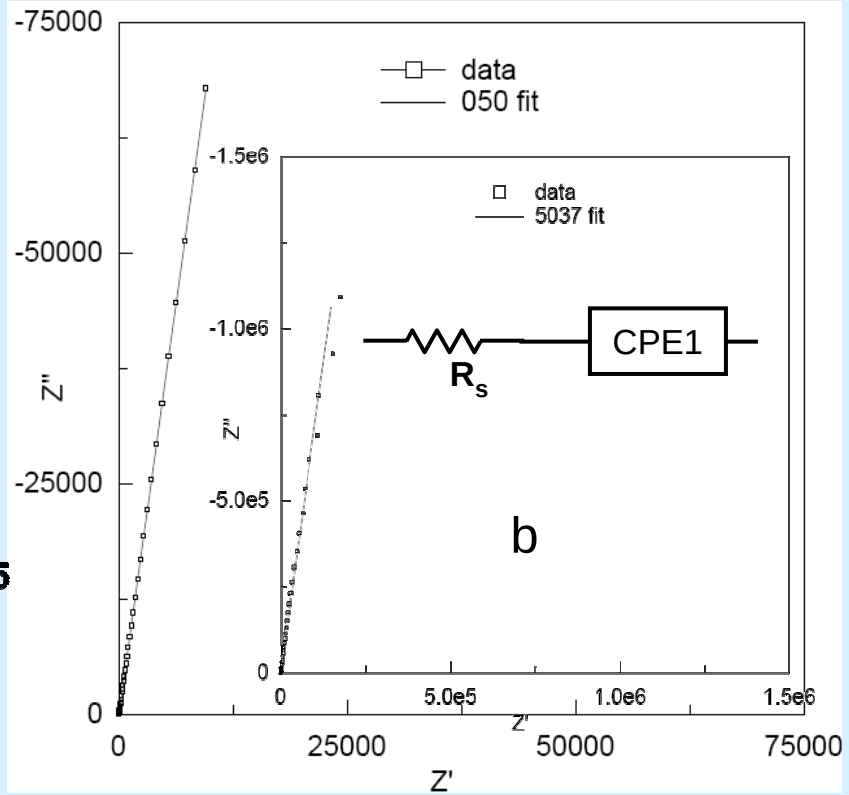
MDEA 050





Determination of MDEA interfacial parameters by LPR and EIS

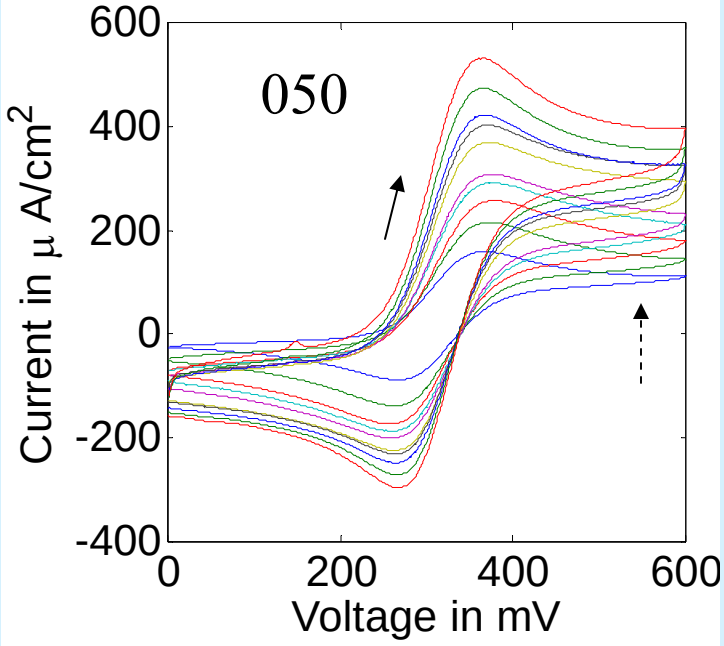


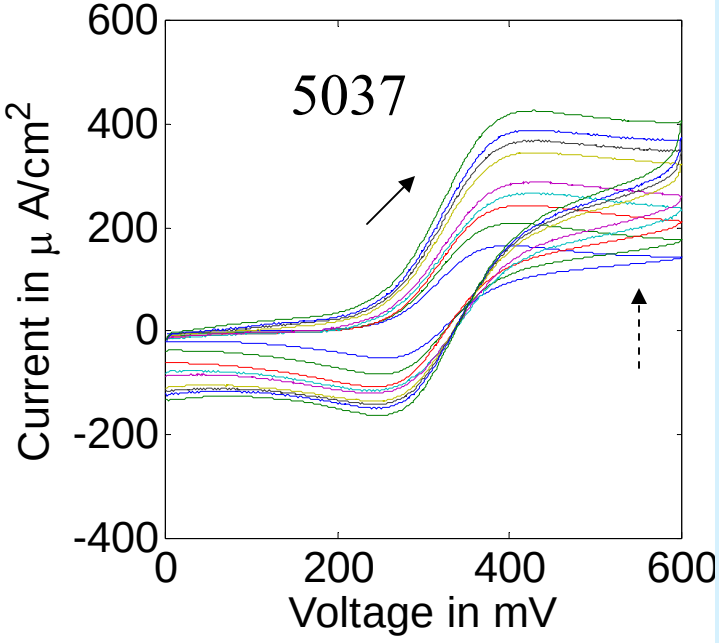


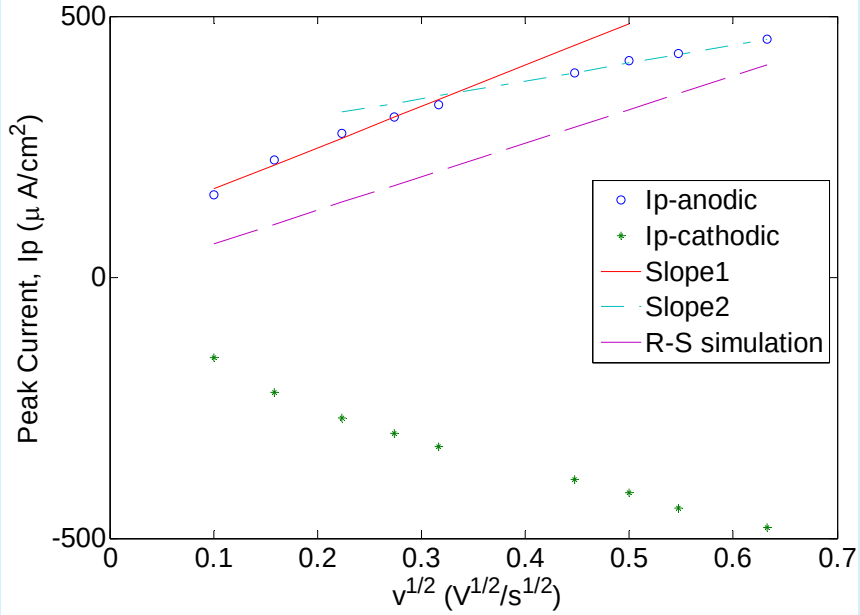
Interfacial and bulk parameters of Au, redox-free system

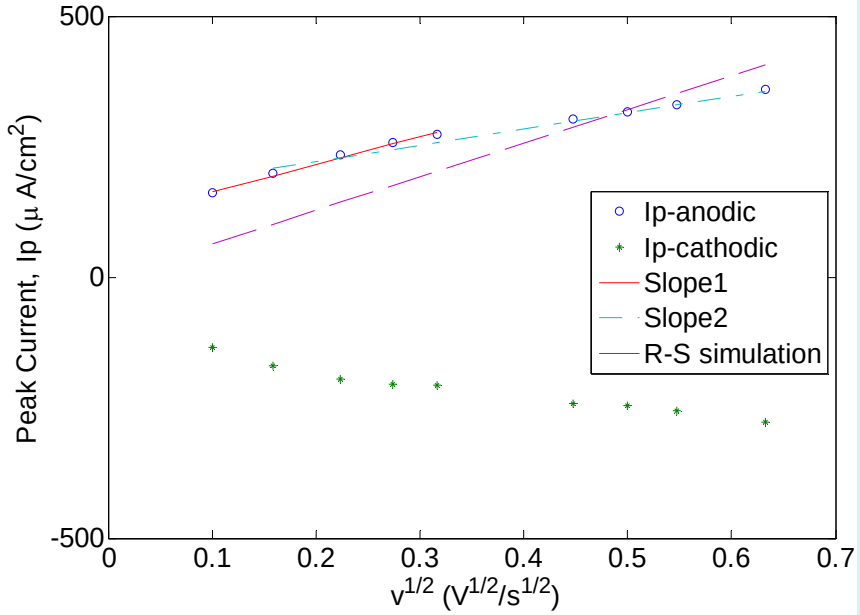
	Active area (radius)	**Resistivity**	**Double layer capacitance by LPR**		**Interfacial parameters by EIS**	
Working Electrodes	cm^2(cm)	ohm-cm	(nF)	(nF/cm^2)	Q ($nS.s^n$); n	R_s (ohm)
MDEA 050	0.10 (0.1784)	15.0	4,000	40,000	2700; 0.91	41.1
5037 glucose sensor	7.3×10^{-4} (0.0152)	18.4	30	41,095	19; 0.91	629
5037 lactate sensor	7.3×10^{-4} (0.0152)	17.9	31	42,465	21; 0.91	603

Cyclic voltammetry in 1mM FcCOOH in 0.1M TRIS/0.1M KCL

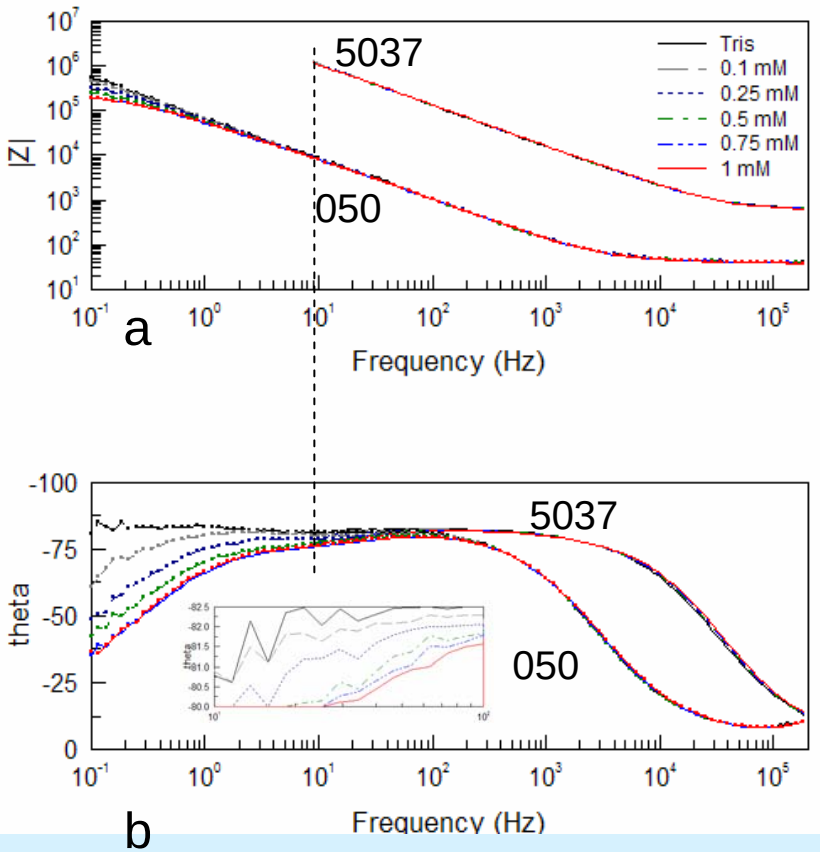


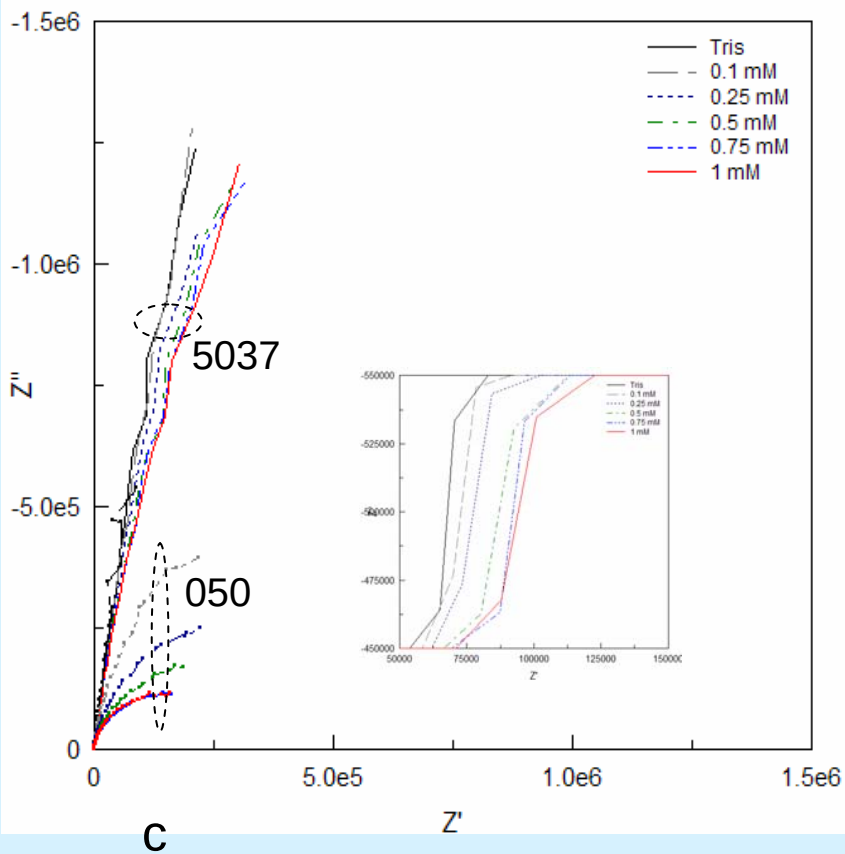




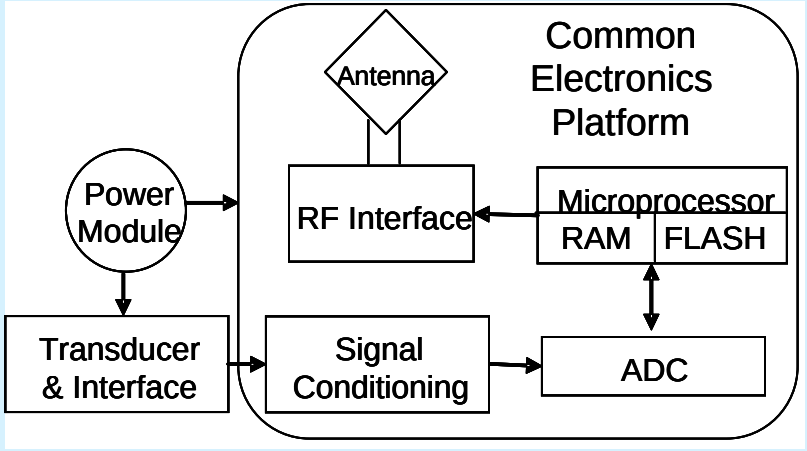


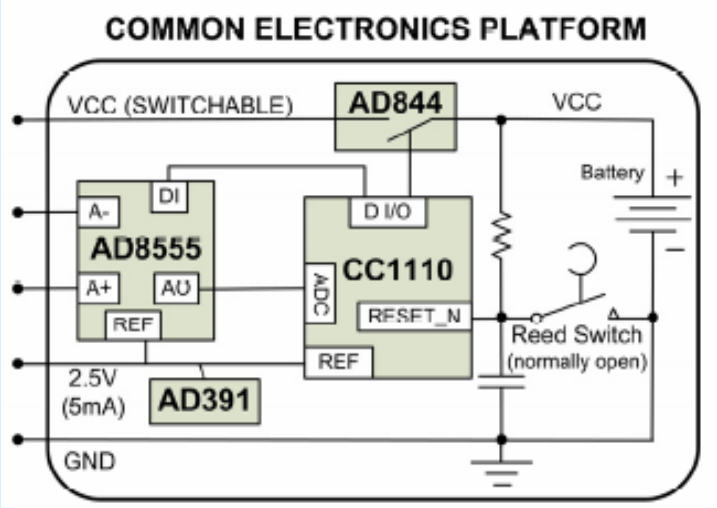
EIS investigation of MDEA behavior



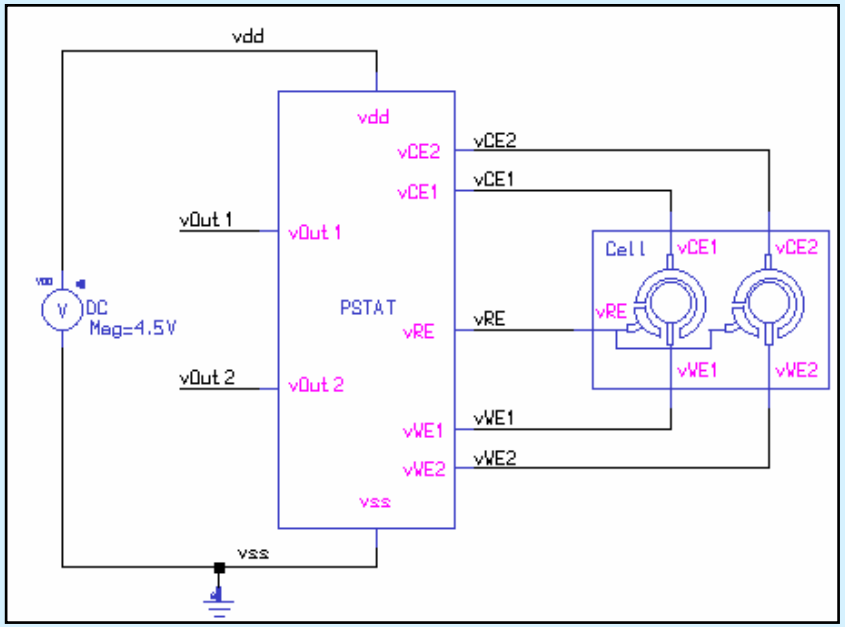


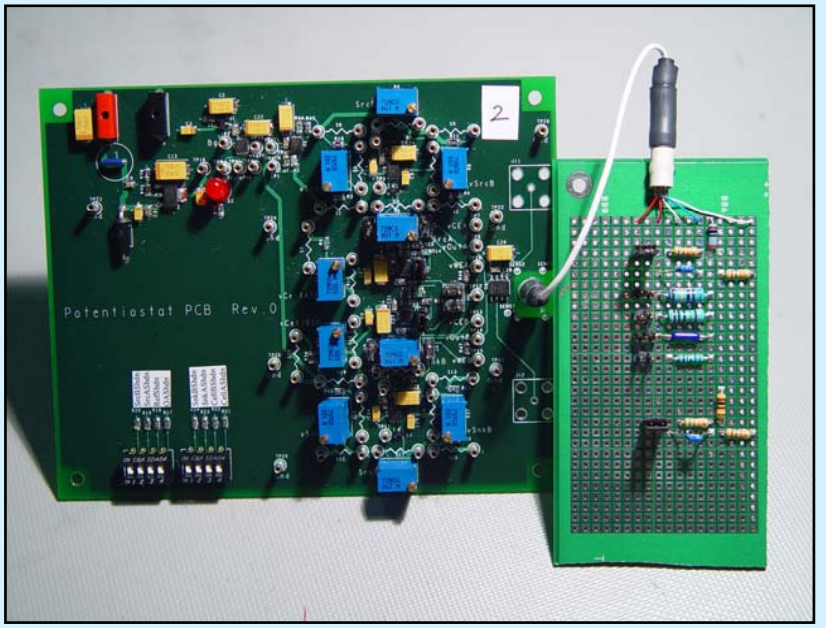
Integrated electronics for implantable wireless biosensor





Towards an on-chip dual potentiostat

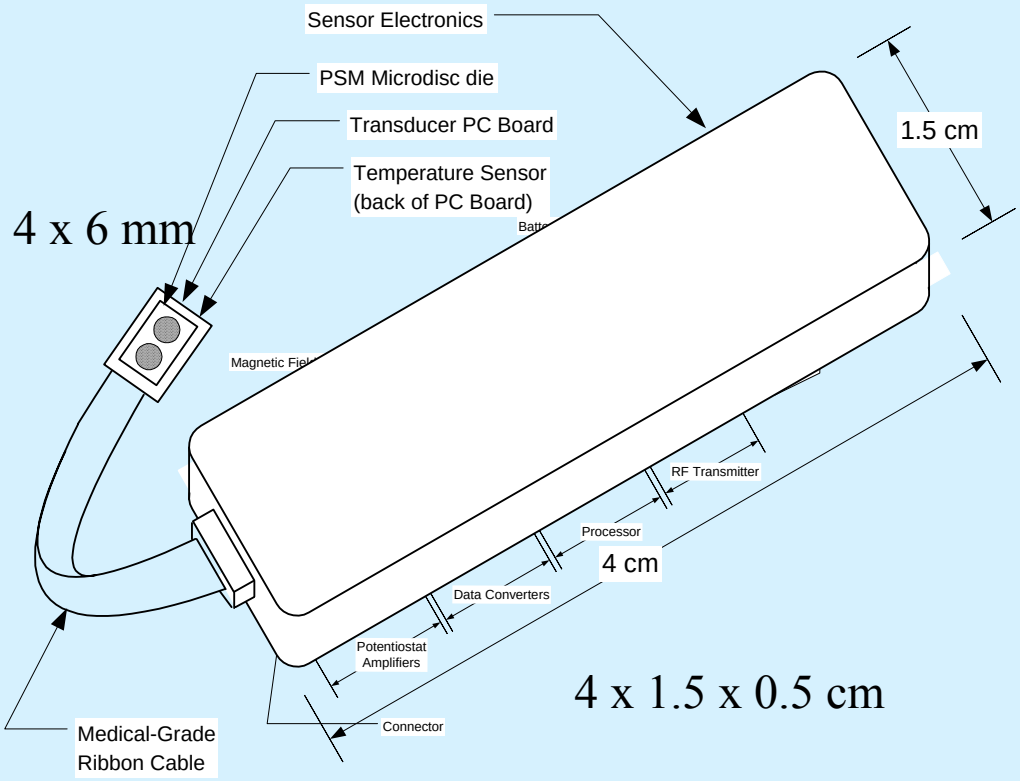




PSMBioChip System

(Physiologic Status Monitoring)

Discrete Prototype Device



ASIC Device

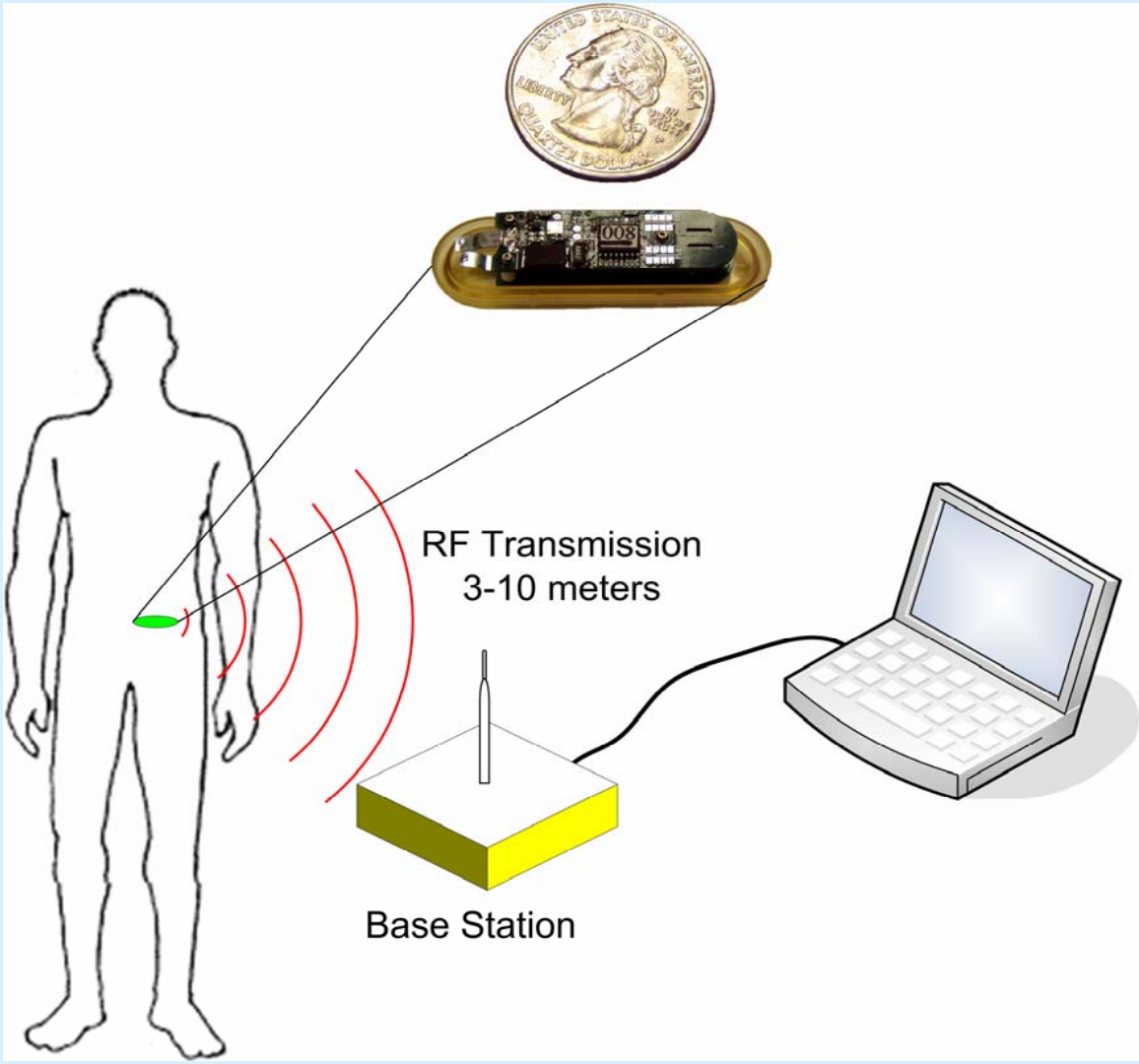
Digital Angel CORPORATION

VERICHIP

An Implantable Biochip for Physiologic Status Monitoring

Glucose, Lactate, pH and Temperature

PSMBioChip Wireless Monitoring



- Implantable wireless telemetry
- Simultaneous glucose and lactate, temperature and possibly pH monitoring

Conclusion

- MDEA WE containing ECC has been designed, fabricated and tested.
- MEAD WE shows enhanced sensitivity due to radial diffusion profile.
- on-chip sensing and telemetry electronics are being developed simultaneously for wireless implantability.

Acknowledgements

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