Cell Clinics: Integrated Potentiostat Design and Capacitance Sensor Testing

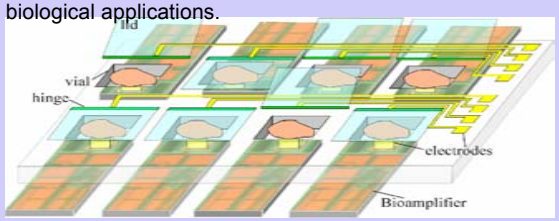
Joel Van Sickel, Somashekar Bangalore Prakash, and Dr. Pamela Abshire

MERIT 2004

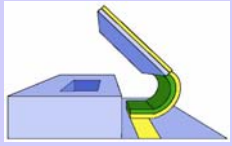
The Institute for Systems Research

Cell Clinics

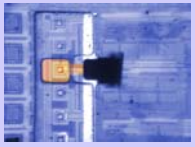
- On chip device used for the study of individual cells.
- Lidded micro vials house each cell.
- Hinges open and close lids based on electrochemical potential.
- Sensors located in micro vials can interface with the cell.
- Physical separation of cells allows for control of every cell's environment.
- Cell Clinics have biomedical, environmental, military, and biological applications.



Closing the Lids



Conceptualization of lidded micro vial



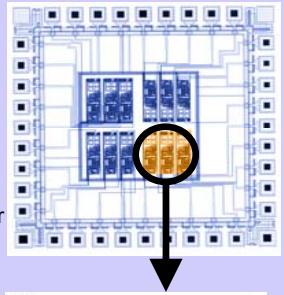
Actual micro vial (orange) and lid (black)

- Hinges are made of two layers, polypyrrole (green) and gold (yellow)
- Polypyrrole changes volume based on the type of reaction.
  - **Reduction** – gains electrons and absorbs cations from solution causing polypyrrole to expand, opening the lid.
  - **Oxidation** – expels electrons and cations, causing polypyrrole to contract, closing the lid.
- Reaction controlled by varying the potential.
- **Potentiostat** used to control the potential
- Gold layer in the hinge serves as a working electrode for the potentiostat.

Potentiostat Design

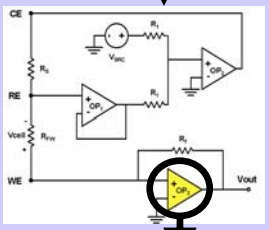
Motivation:

- Shrink standard potentiostats (which are HUGE! 31 kg and 1440 cm^2) to an on chip solution.
- Allow individual control over the micro vial lids.
- Provide a sensor to monitor the electrochemical reaction.

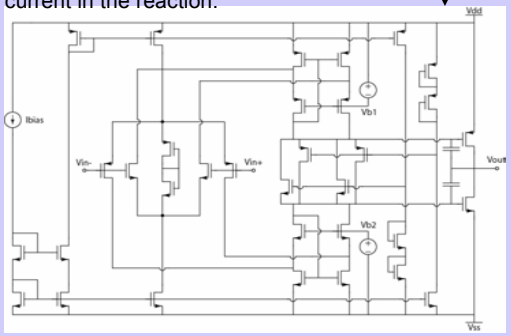


Requirements:

- Operation at 3 V supply, rail to rail.
- Area smaller than 0.125 mm^2.
- Ability to drive 1.5 mA with V_{cell} at -1 V. (see middle figure)
- Capability to measure current in the reaction.



Potentiostat



Custom wide swing operational amplifier designed for this project

Results:

- Achieved design requirements.
- Shrank potentiostat to approximately **0.073 mm^2**.
- Submitted 4 Potentiostats on single chip (top picture) for fabrication at MOSIS.

Capacitance Sensor

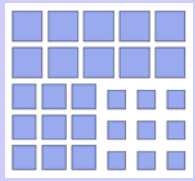
Introduction:

- Will use sensor to determine health/location of a cell.
- Design based on fingerprint sensors.
- Cell acts as one plate of a capacitor.
- Measures change in capacitance with charge sharing.
- Testing done with 3 axis translation station, picomotor, and needle to probe the different size sensors.

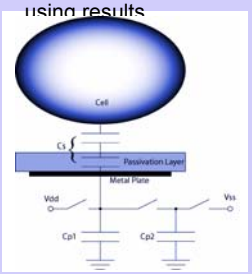
Results:

- Discovered that chip acts as a light sensor!
- Destroyed many chips with needle.
- Observed extreme sensitivity to needle position.
- Determined that expected parasitic capacitances were inconsistent with results.
- Developed method to successfully test chip.
- Estimated parasitic capacitances using results

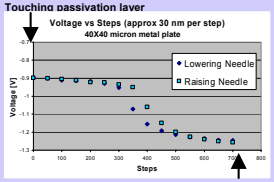
Test Set Up



Metal Pad Layout with 40X40, 30X30 and 20X20 micron sensor pads



Touching passivation layer



About 21 microns away

Future Work

- Test the potetiostat.
- Make potentiostat even smaller.
- Package capacitance sensor and test with cells.
- Design a 2-D array of capacitance sensors

Acknowledgements

I thank Som the grad student I worked with and Dr. Abshire for all of their help. Dr. Smela and her group for all the work done with micro actuators, Mosis for fabrication of chips, NSF and UMD for supporting the Merit program.