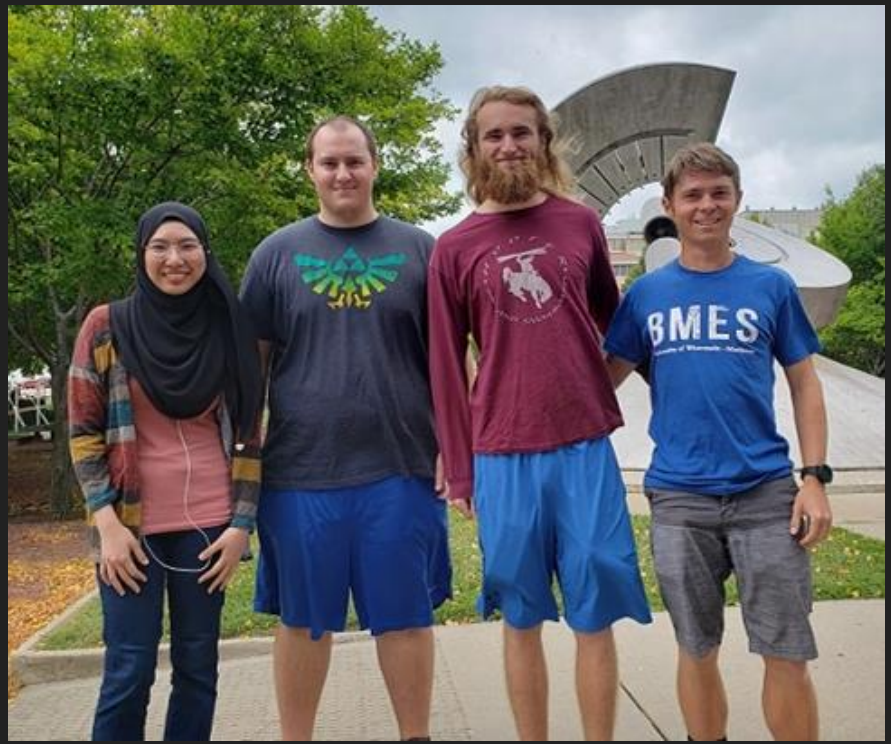
Diagnosing Compartment Syndrome with pH

Project Overview

Client: Dr. Christopher Doro
Advisor: Dr. Amit Nimunkar

Team Leader: Jonah Mudge
BWIG and BPAG:
Lucas Ratajczyk
BSAC: Syafiqah Saidin
Communicator: Hunter Huth



Problem Statement

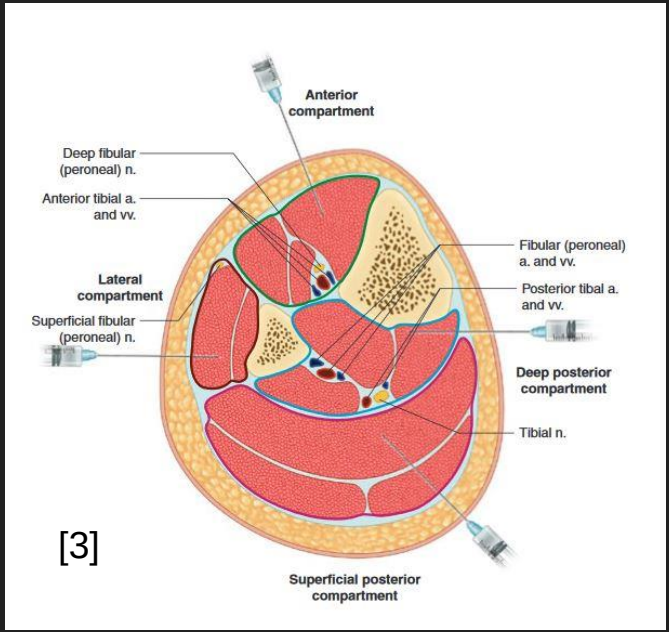
- Acute Compartment Syndrome (ACS) is difficult to diagnose
  - How do we detect muscle ischemia prior to muscle death?
  - ISFET decided upon by previous group
- Design physical (and software) display and user interface so physicians can interact with pH probe
- Conduct animal testing to verify efficacy of pH monitoring in detecting ACS
- Miniaturize ISFET probe

[1]

Background (Biology)

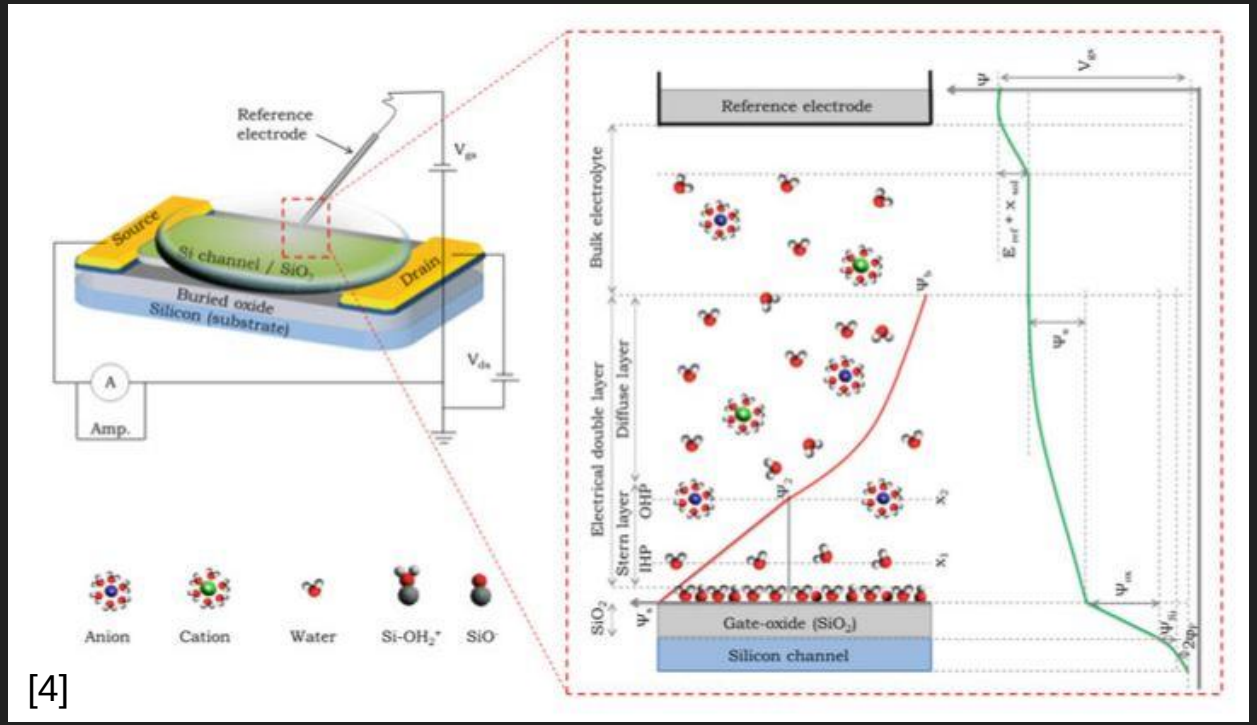
Fracture or Blockage → Pressure Increase → Metabolite Build-Up → Ischemia, Tissue Death, Necrosis

If no decision is reached by 6 hours after injury/symptom onset, fasciotomy is done [3].



Background (Technology)

ISFET: Ion-Sensitive Field-Effect Transistor



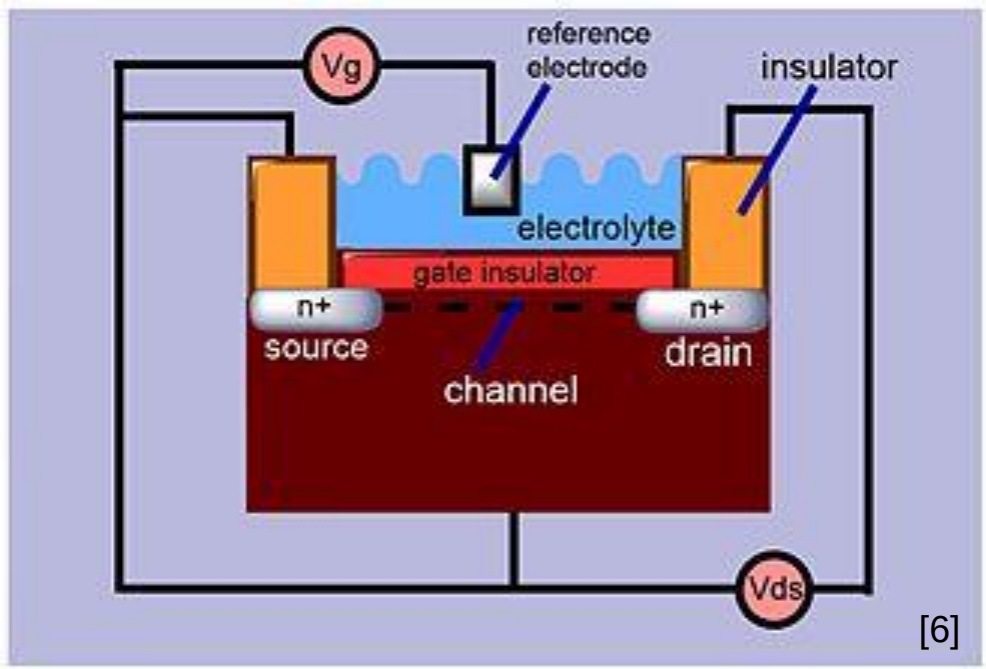
[4]

Background (Technology)

- Reference electrode to “offset”
- Source and drain measure H+
- Nernst equation to solve:

$$E = \frac{RT}{zF} \ln \frac{[ion]_o}{[ion]_i}$$

[5]



[6]

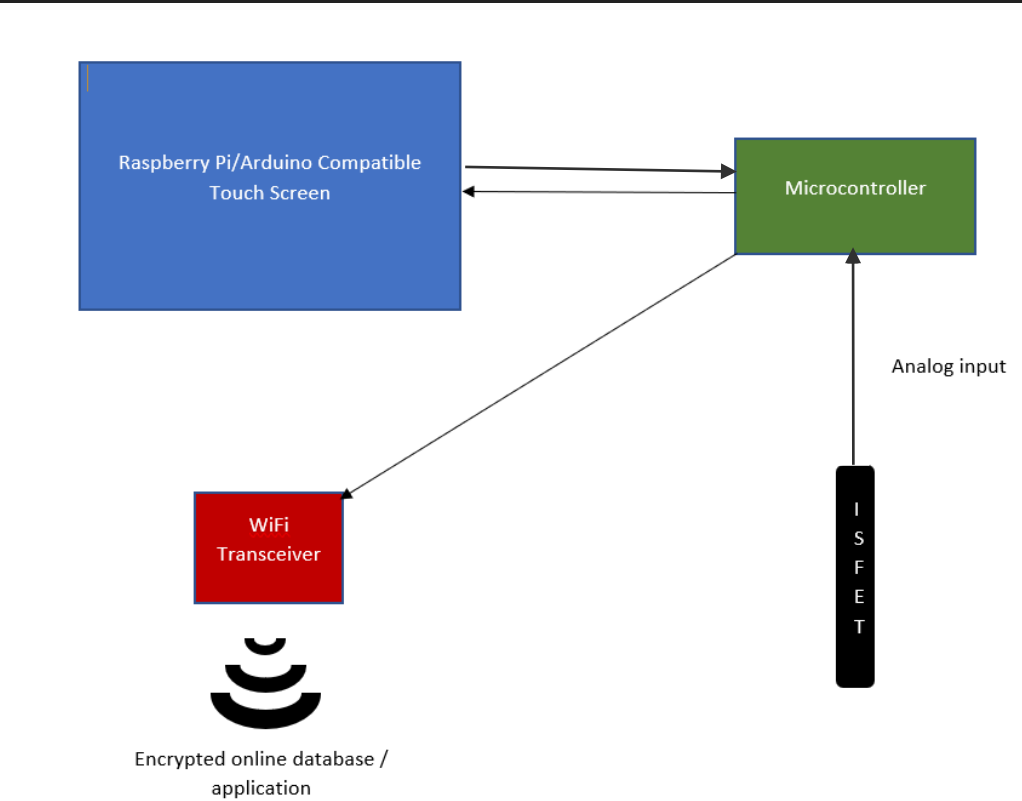
PDS

- Device to display pH and allow physicians to record/interact with data
  - Reliable for clinical use
  - Easy to work with in possibly high-stress OR environment
- Able to record at least 48 hours of pH measurements
- Accurately measure and display the pH that relates to compartment syndrome (pH 5 to 7)
- Detachable and replaceable sensor/needle
- The sensor must fit through the tip of a 16 gauge needle
- Should not cause any infection in the muscle compartment or cause electrical shock

Design Possibilities - Touch screen

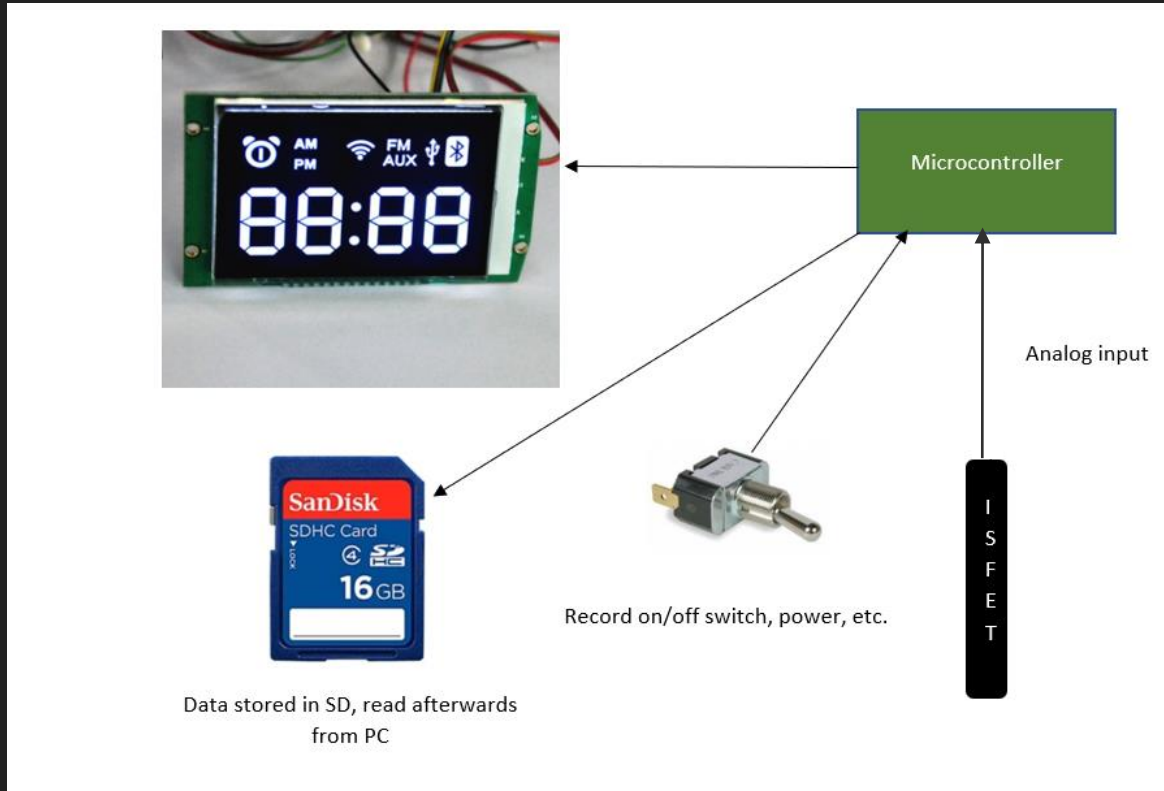
- Very portable
- Saving data to cloud minimizes risks of losing it

- Easy to contaminate screen
- Sterilizability?



Design Possibilities - LCD

- Less complicated components
- Easier to interact with while in OR
- Simple to retrieve data after recording
- Less functionality
- Need to manually transfer SD card



Design Possibilities - Phone/Computer

- pH displayed through device with app
- Recording easy to access
- Patient info security?
- Complex

Personal physician / hospital device

Microcontroller

Analog input

Data stored on device memory

Physician inputs command from device

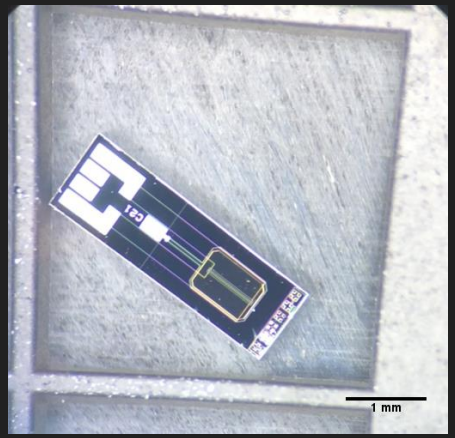
ISFET

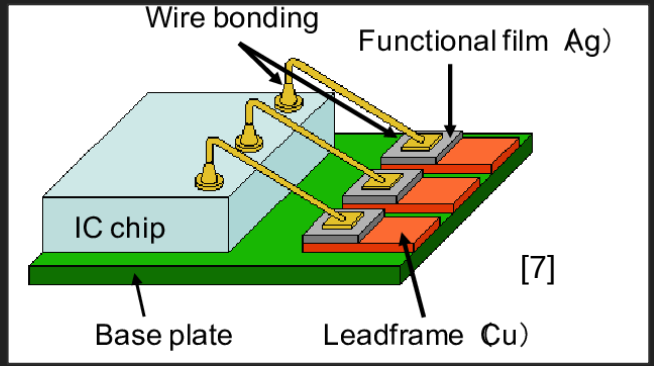
Design Matrix

Criteria	Touch	LCD	Phone/Computer
Reliability (25)	20	25	20
Safety (25)	20	25	15
Resilience (20)	13	20	15
Portability (15)	15	8	12
Ease of Use (10)	6	9	7
Cost (5)	3	5	4
Total (100)	77	92	73

Miniaturization of the previous prototype

- Must miniaturize the ISFET chip and the reference electrode.
- Contacting manufacturers that manufacture on this scale
- Discussing with the Wisconsin Center for Nanoscale Technology about scaling the previous prototype down to fit into a 16-gauge needle
  - Wire-bonding
  - Solder reflow oven





Future Work

- Investigate nanofabrication option
- Fix the prototype from previous semesters
- Begin testing with dogs
- Initiate IRB approval process for future human testing

References

[1] Amazon.com. [online] Available at: https://www.google.com/url?sa=i&source=images&cd=&ved=2ahUKEwintbbVl4HlAhVBgp4KHcztBSMQjRx6BAgBEAQ&url=https%3A%2F%2Fwww.amazon.com%2FRaspberry-Pi-7-Touchscreen-Display%2Fdp%2FB014WKCFR4&psig=AOvVaw3DHi2v_7jyj74D-iTnCXNx&ust=1570229713025682 [Accessed 30 Sept 2019]

[2] C. Doro, private communication, Sep 2019.

[3] D. Purcell, B. A. Terry, and B. R. Sharp, “Acute Compartment Syndrome,” in *Emergency Orthopedics Handbook*, D. Purcell, S. A. Chinai, B. R. Allen, and M. Davenport, Eds. Cham: Springer International Publishing, 2019, pp. 79–85.

[4] M. J. Schoning and A. Poghossian, Eds., *Label-free biosensing*. New York, NY: Springer Berlin Heidelberg, 2018.

[5] Krishna, R (2018). *Chemistry Notes - Electrochemistry.* [online] Available at: https://www.cbsetuts.com/neet-chemistry-notes-electrochemistry-nernst-equation/ [Accessed 2 Oct. 2019].

[6] Grour T., Najari M., Mehdi A., and Lassaad El Mir Mabrouk (2018). *Graphene field-effect transistor for pH sensing application: Compact modelling and simulation study.* [online[Research Gate. Available at: https://www.researchgate.net/figure/Structure-of-the-Gr-ISFET-with-Aluminum-oxide-Al2O3-sensing-film_fig1_325804457 [Accessed 2 Oct. 2019].

[7] Tsutsui, Y., Yamasaki, K., Maekawa, K., Niizeki, T., Bucheeri, A., Mita, M., Matsuba, Y., Terada, N. and Saito, H. (2019). *Size Effect of Ag Nanoparticles on Laser Sintering and Wire Bondability*. [online] Research Gate. Available at: https://www.researchgate.net/publication/251931958_Size_Effect_of_Ag_Nanoparticles_on_Laser_Sintering_and_Wire_Bondability [Accessed 1 Oct. 2019].

Acknowledgements

Department of Biomedical Engineering
UNIVERSITY OF WISCONSIN–MADISON

Dr. Amit Nimunkar

Dr. Christopher Doro, MD