Design and Test of a Mechanical System for Electrochemical Oxygen Sensors with *in vivo* Applications

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ABSTRACT

A freestanding micromachined electrochemical oxygen sensor has been developed for the purpose of minimally invasive biomedical applications. When applied to these physiological environments, it is important to understand the physical interactions between this environment and the sensor. These interactions could affect the functionality of the sensor. An anticipated use is applying this sensor within a muscle, which has unknown effects on the sensor. To validate the performance of the sensor in a muscular environment, a mechanical system has been developed that tests the sensor in these conditions using an externally applied force and a muscle phantom. The sensor performance has be tested in saline before and after undergoing an applied load, that progressively increased, for comparison. After undergoing testing, this comparison showed no significant difference in current output validating that intramuscular forces have minimal to no significant effect on the performance of these sensors.

MOTIVATION

Objective

- Develope a mechanical system to mimic the forces and properties of muscle tissue for testing of applications in animal and human skeletal muscle
- Understand how physical interactions of a surrounding environment affect the performance of an oxygen microsensor

Sensor

- Includes 3 electrodes, an electrolyte, and an oxygen permeable membrane [1]
- Fabricated with a backing and spacer for improved rigidity
- An oxygen reduction reaction occurs when the sensor is applied with a voltage and produces a current that is proportional to the oxygen level [1]
- Measured using a potentiostat and Linear Sweep Voltammetry (LSV) scans

Fig 1. Electrochemical oxygen microsensor

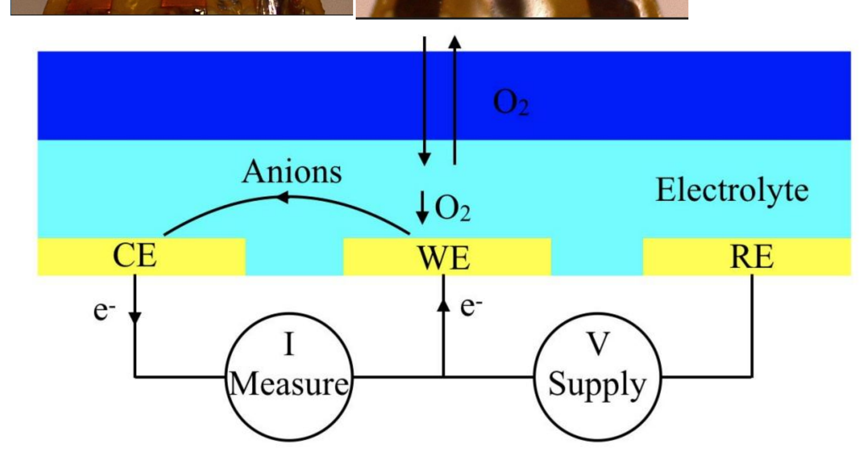

Fig 2. Operation of an electrochemical oxygen sensor [1]

Mechanical System

- Muscle phantom must closely match muscle tissue mechanical properties which are quantifiable through the modulus of the material
- Intramuscular pressure (IMP) best quantifies how the muscle fibers and surrounding fluid apply force to the inserted sensor in an in-vivo environment
- The IMP of skeletal muscle was found to range between 0-35 mmHg [2]

METHODS

Process

- Scans in saline are conducted before and after experiencing mechanical testing for performance comparison
- Scans are conducted as the applied external load on the sensor within the muscle phantom progressively increases

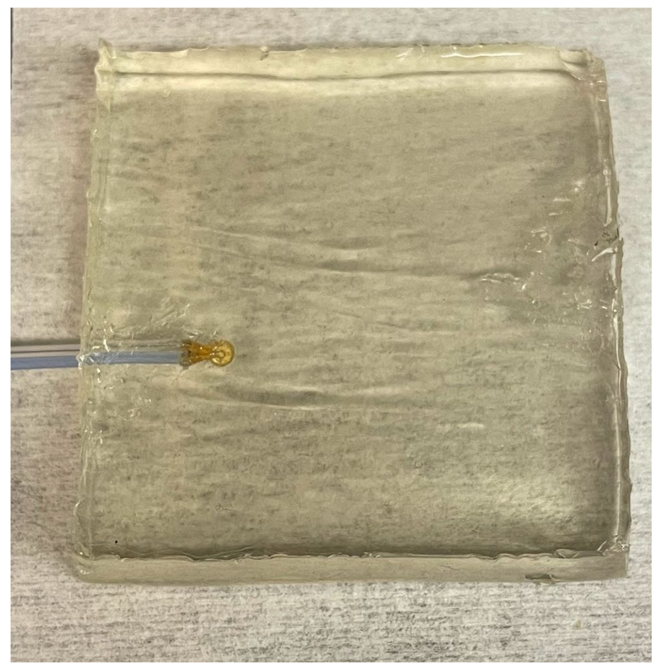

Fig 3. Microsensor inserted into gelatin muscle phantom

Fig 4. Muscle phantom with inserted sensor undergoing applied external load

Muscle Phantom Recipe

- 10wt% gelatin mixture was selected for a similar modulus to muscle [3]
  - 3 g gelatin powder
  - 27 ml DI water
  - Heat mixture to 90 °C
  - Refrigerate overnight

Pressure Values

10g	7.73 mmHg
100g	14.97 mmHg
200g	19.48 mmHg
250g	24.35 mmHg
500g	27.84 mmHg

RESULTS

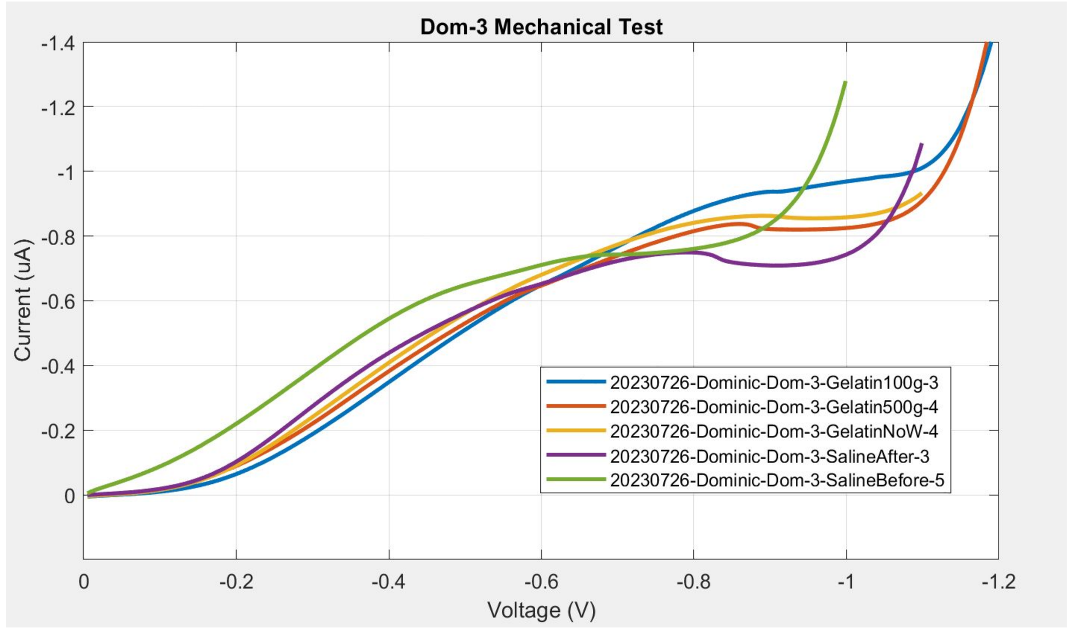

Fig 5. Graph of LSV scans with output current

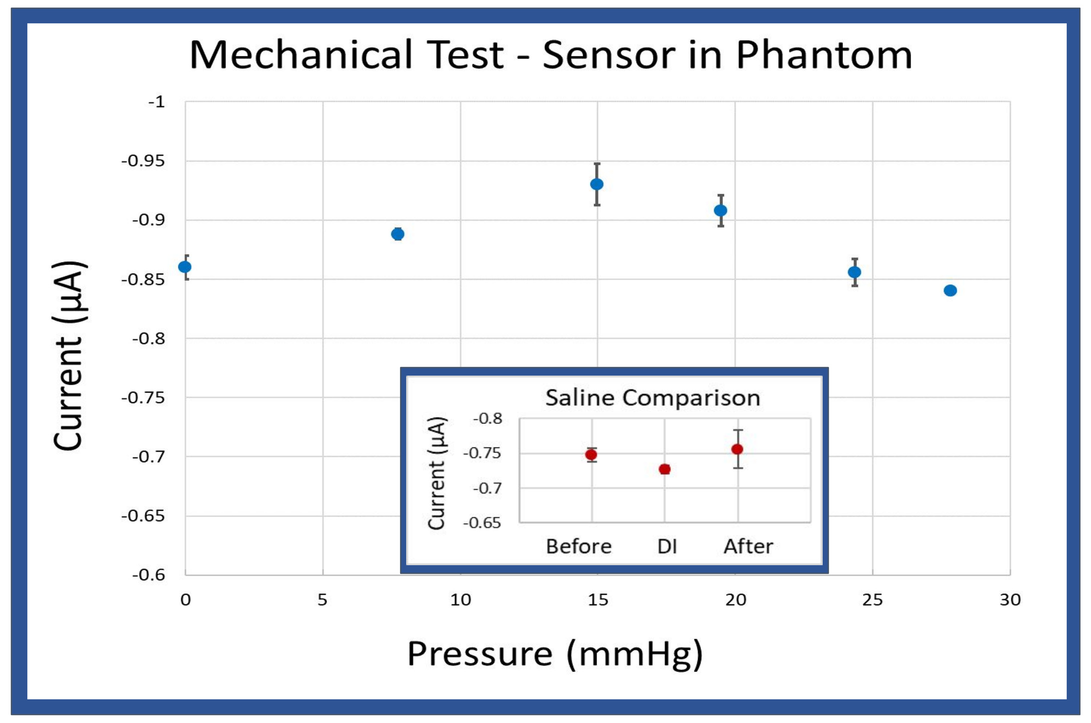

Fig 6. Plot of the average current output at each applied pressure

- Performance was determined by analyzing the sensor current output in the LSV scans
- The average peak current under each pressure value is similar showing unsubstantial change in performance
- The saline comparison shows that similar current output is read before and after undergoing the mechanical test

CONCLUSION

- This test has been used to validate the performance of an electrochemical oxygen sensor, with an applied structural aid, under different applied external loading
- A muscle phantom and external loading have been successfully implemented mimicking the mechanical properties of muscle tissue and intramuscular forces
- This system can be used to further validate the performance of different biosensors for in-vivo applications
- Improvements on the structural composition of this oxygen microsensor and the effects on the performance can be further tested with this system

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