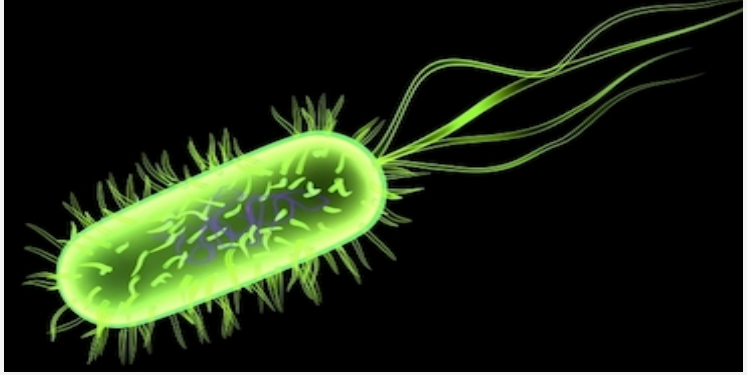


Laser Carbonized Electrodes for Foodborne Pathogen Detection in Large Sample Volumes via Vacuum Driven Flow

Nicholas D. Cavallaro,
C. Gomes, E. S. McLamore

UF IFAS
UNIVERSITY of FLORIDA

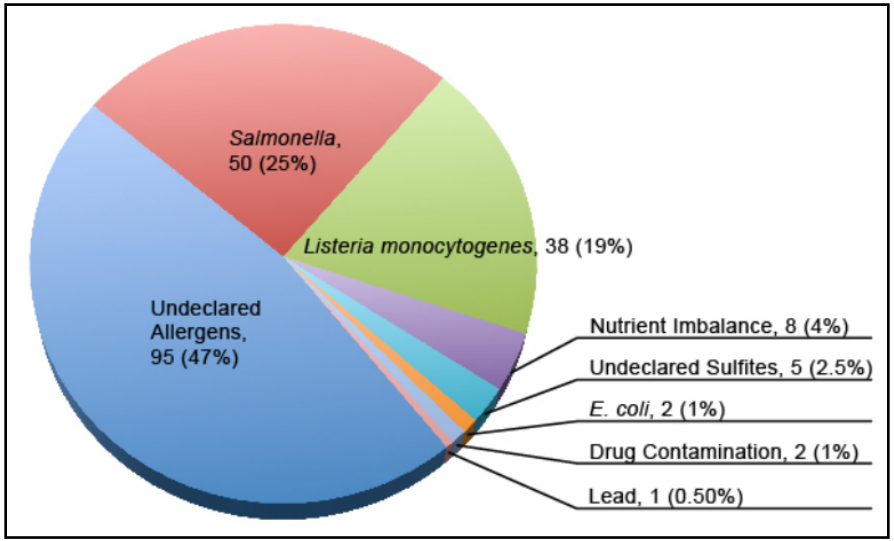
IOWA STATE
UNIVERSITY

Foodborne Pathogens

Everyone deserves access to safe food.

- 1400 Deaths
- 9.4M Illnesses
- 3.6M Illnesses from Pathogenic Bacteria
- 56K Hospitalizations

: Distribution of Primary RFR Entries by Food Safety Hazard, Year 5

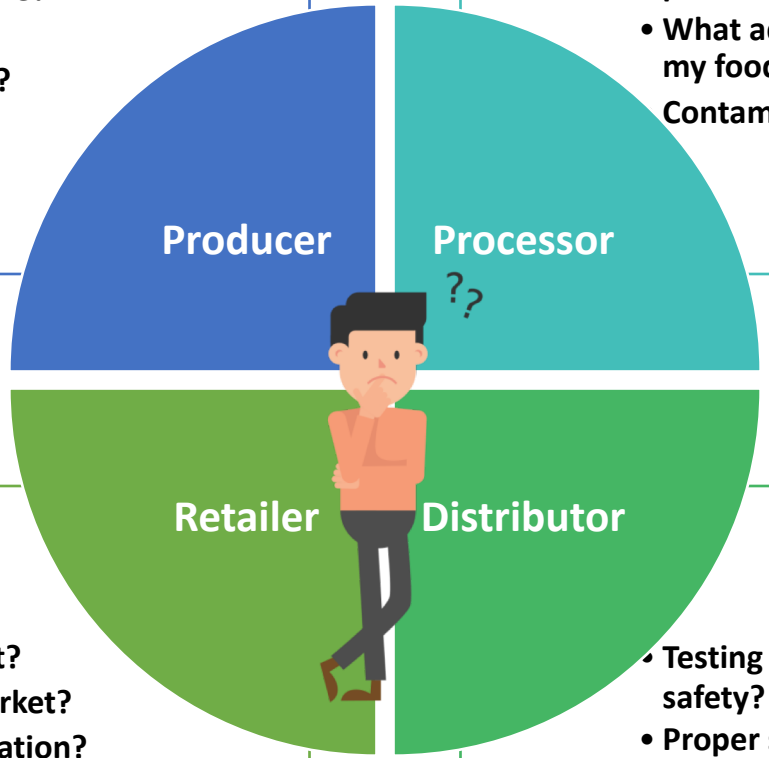


Years 1-4 Pie Charts can be accessed in The Reportable Food Registry: Targeting Inspection Resources and Identifying Patterns of Adulteration Fourth Annual Report: September 8, 2010 - September 7, 2013.

- Small Farmers?
- Big Agriculture?
- Organic?
- Non-organic?
- GMOs?

- Are the processing plants safe?
- What additives are in my foods?

Contamination?

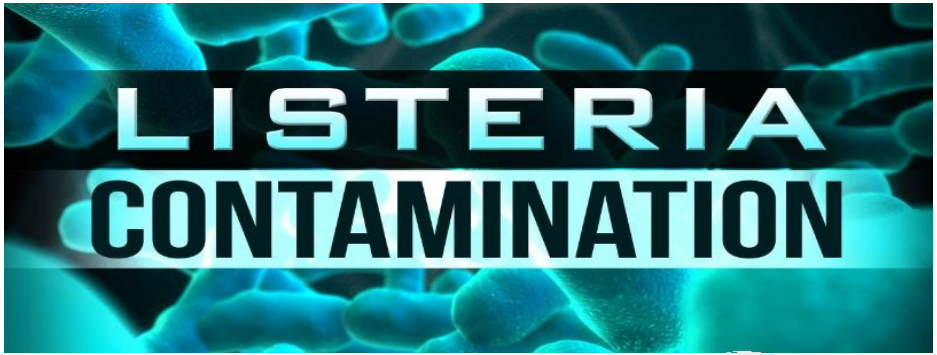


- Supermarket?
- Farmer's Market?
- Proper Sanitation?
- Proper refrigeration?

- Testing for consumer safety?
- Proper storage?
- Safe handling?

Listeria monocytogenes

- Listeriosis
- High Risk Populations
- Recalls
- Need for preventative detection



Food Safety Regulation

FDA FOOD SAFETY MODERNIZATION ACT

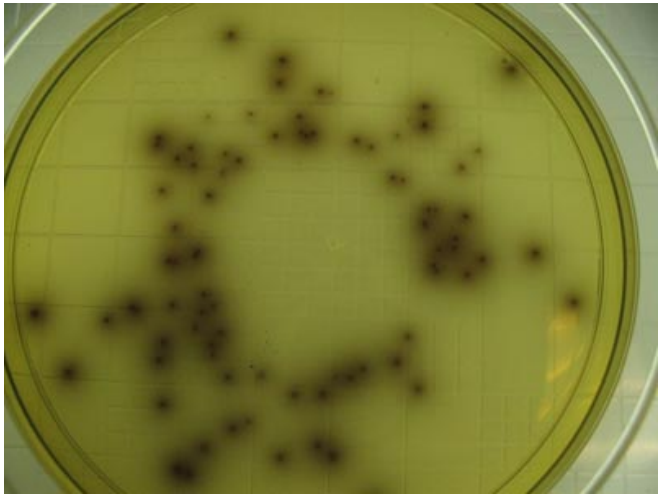
FDA

USDA

Hazard•Analysis HACCP Critical•Control•Point

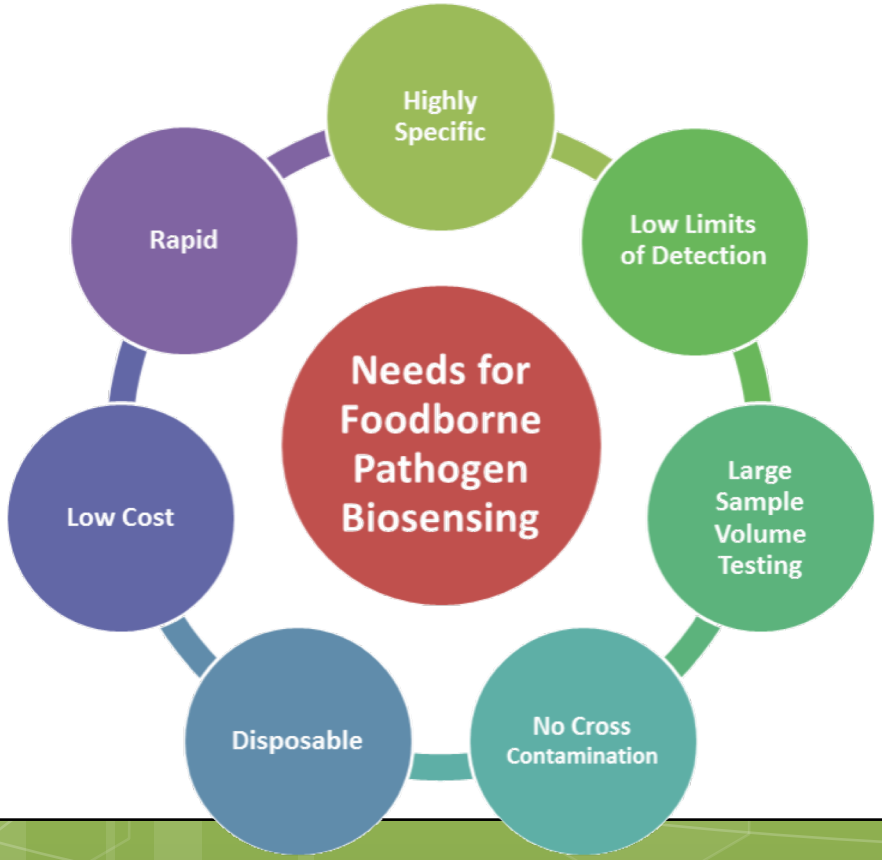
Currently Accepted Detection Techniques

- Analytical Sampling
- Incubation Period
- Colony Counting
- Polymerase Chain Reaction (PCR)



This research aims to develop the fundamental chemistry and physics required for establishing a biosensor technology for rapid and accurate microbial detection, potentially improving the efficacy of current HACCP systems in future studies.

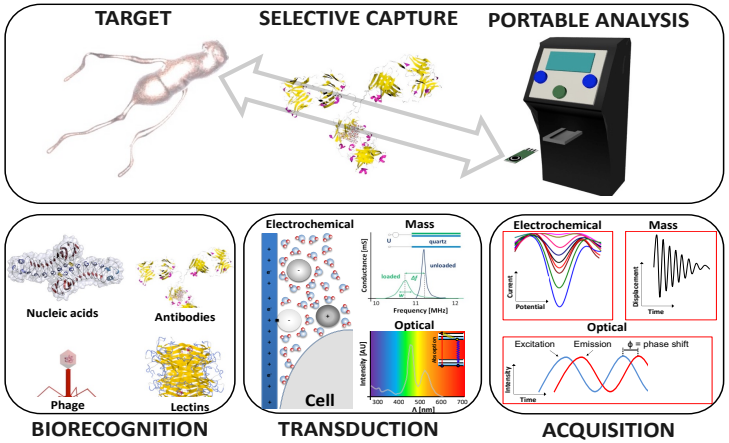
Nanobiosensors



Biosensor Variety

- Performance tradeoffs among biorecognition elements
- Varied transduction approaches
- Nanomaterials enhance biorecognition/transduction

Source: Vanegas et. al. (2017)

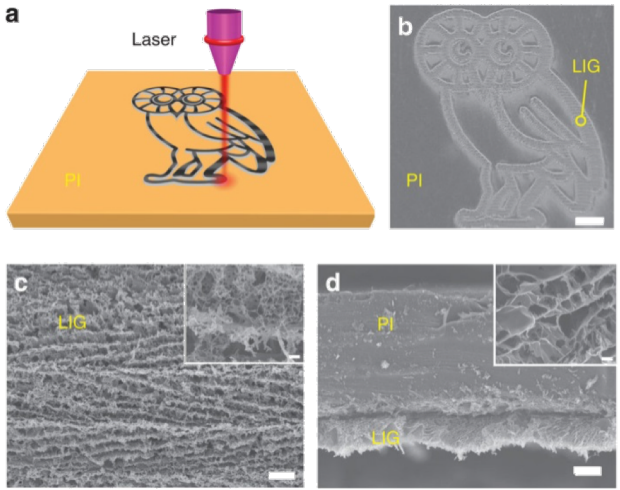


Research Goal

The overall goal of this research is to develop low cost, laser carbonized electrodes for rapid, point of use detection of *Listeria monocytogenes* in large sample volumes via vacuum driven flow directly through the electrodes.

Laser Induced/Scribed Graphene

Lin et. al. (2014) develops LIG from polyimide films

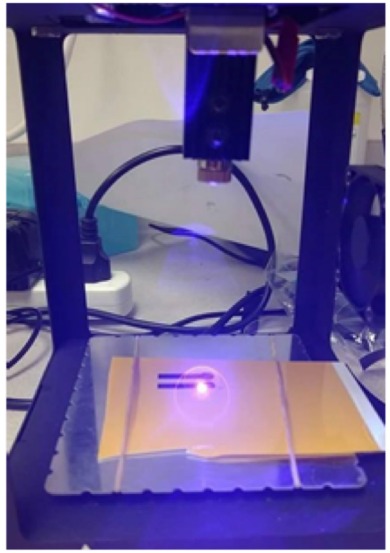


LIG/LSG for Nanosensing and Biosensing

- Tehrani et. al. (2016)
  - Glucose sensing
- Vanegas et. al (2018)
  - Biogenic amine sensing
- Garland et. al. (2018)
  - Nitrogen sensing in soil

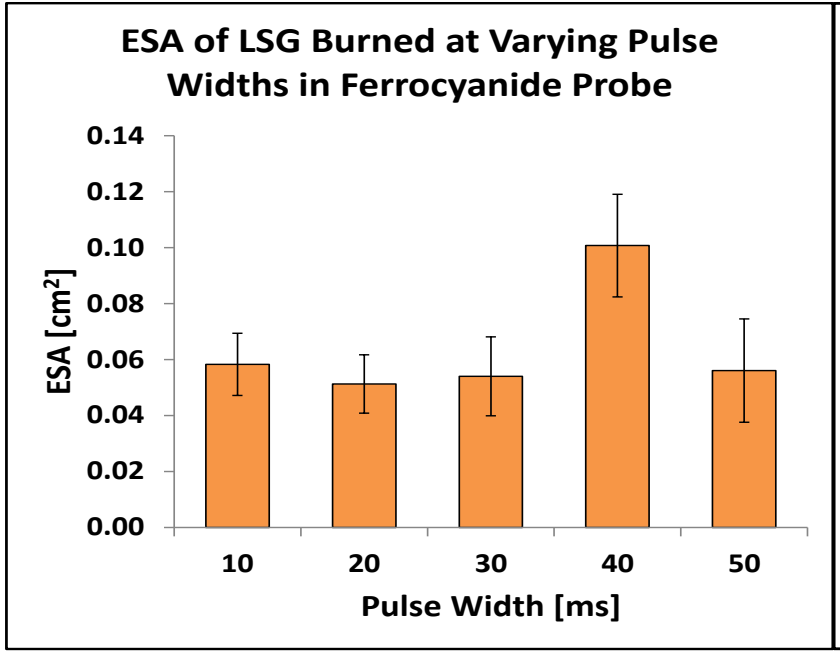
Electrode Fabrication

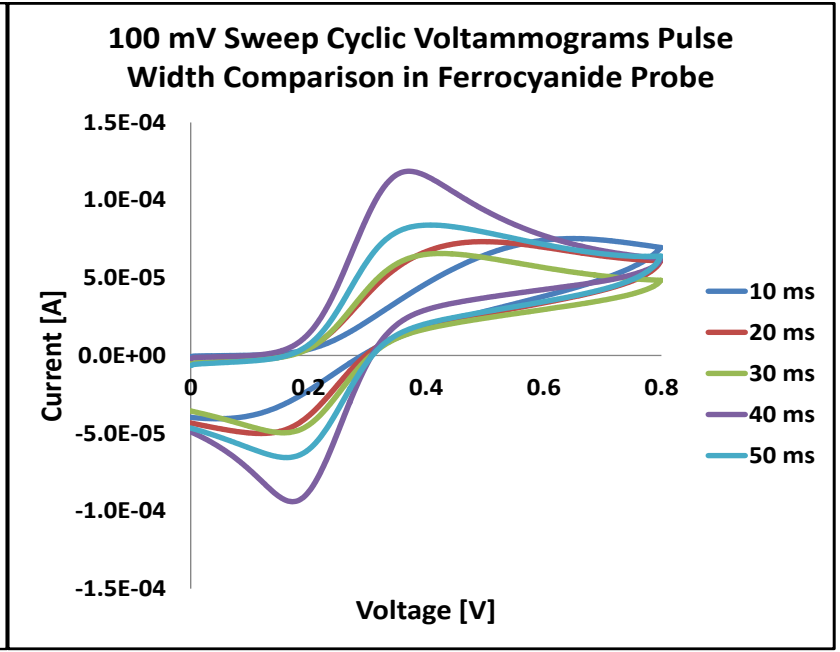
Single Working Electrode



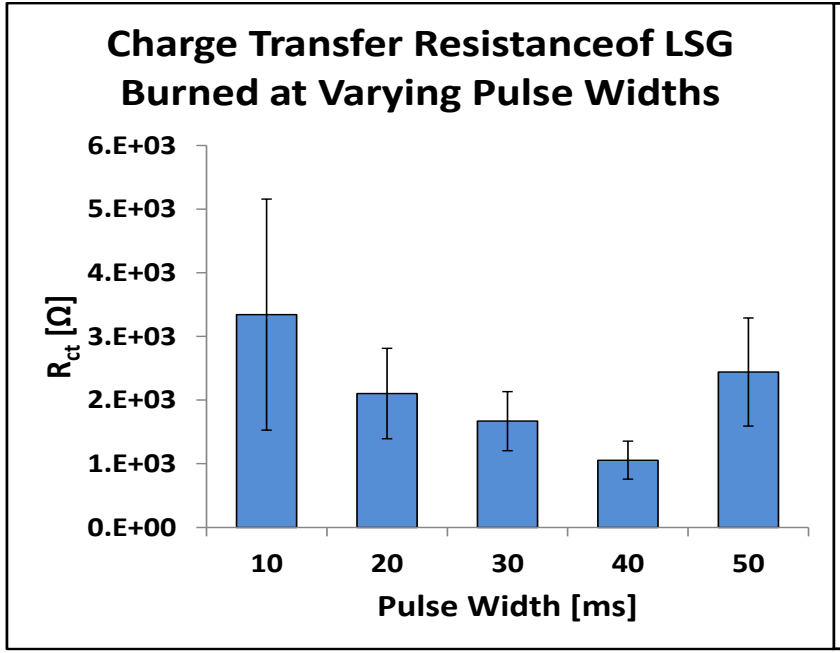
Full Biosensor Test Strip w/ WE, CE, RE

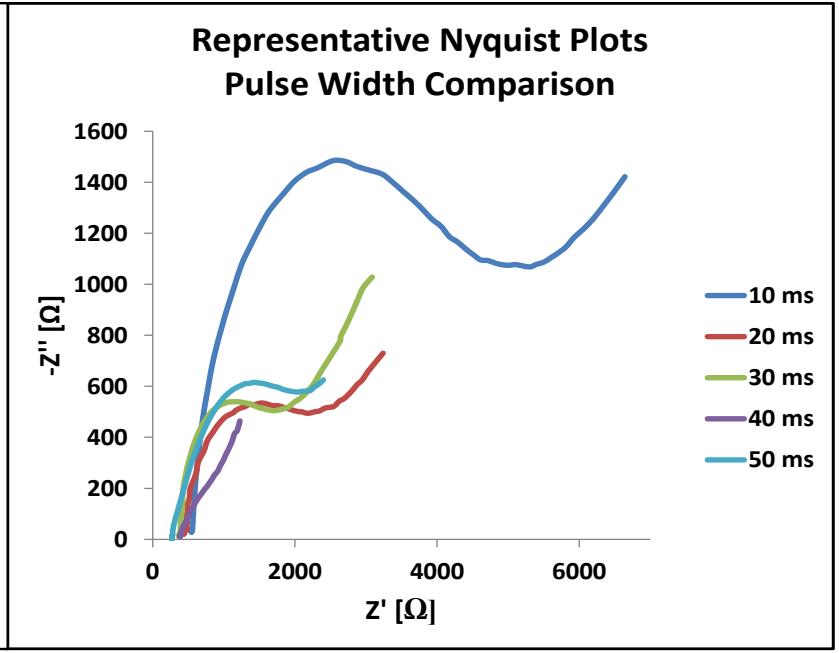
ESA Results


ESA of LSG Burned at Varying Pulse Widths in Ferrocyanide Probe
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
ESA [cm²]
10
20
30
40
50
Pulse Width [ms]

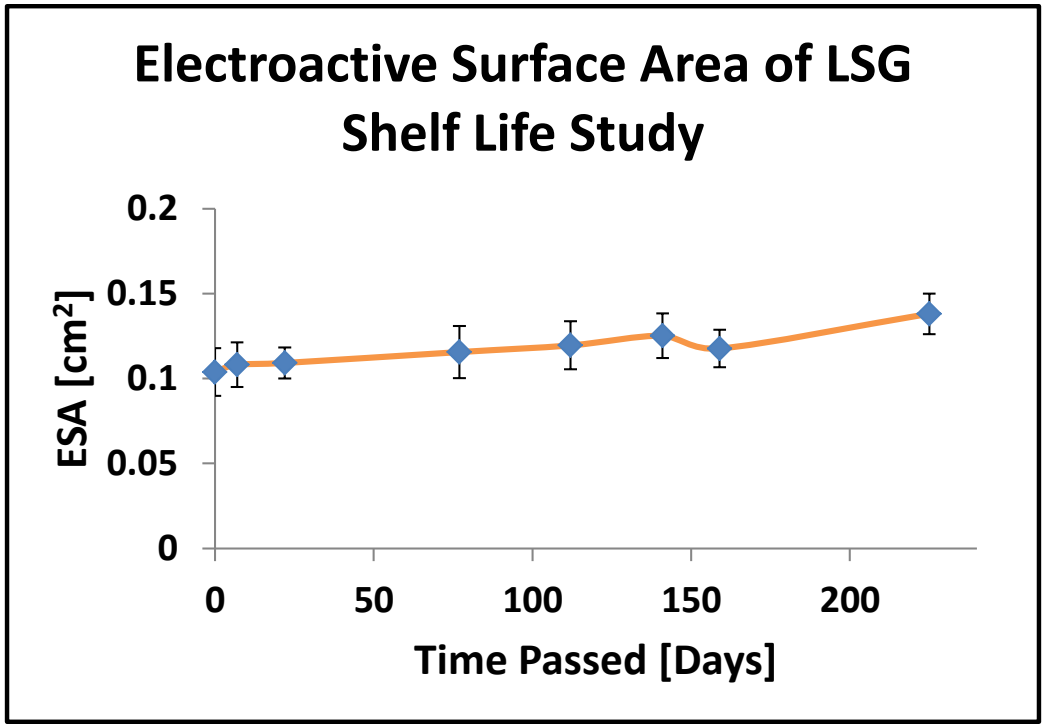

100 mV Sweep Cyclic Voltammograms Pulse Width Comparison in Ferrocyanide Probe
1.5E-04
1.0E-04
5.0E-05
0.0E+00
-5.0E-05
-1.0E-04
-1.5E-04
Current [A]
0
0.2
0.4
0.6
0.8
Voltage [V]
10 ms
20 ms
30 ms
40 ms
50 ms

EIS Results

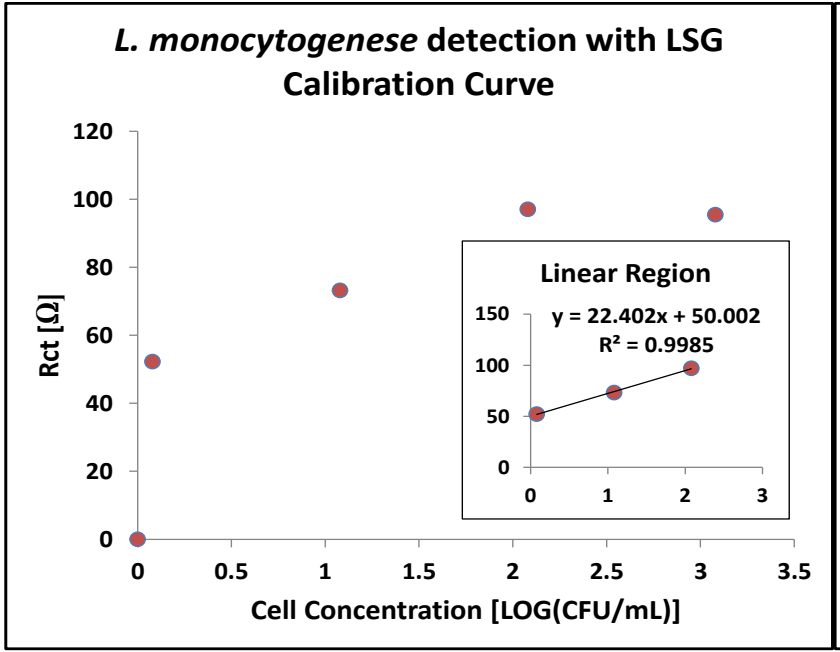

Charge Transfer Resistanceof LSG Burned at Varying Pulse Widths
6.E+03
5.E+03
4.E+03
3.E+03
2.E+03
1.E+03
0.E+00
R_{ct} [Ω]
10
20
30
40
50
Pulse Width [ms]

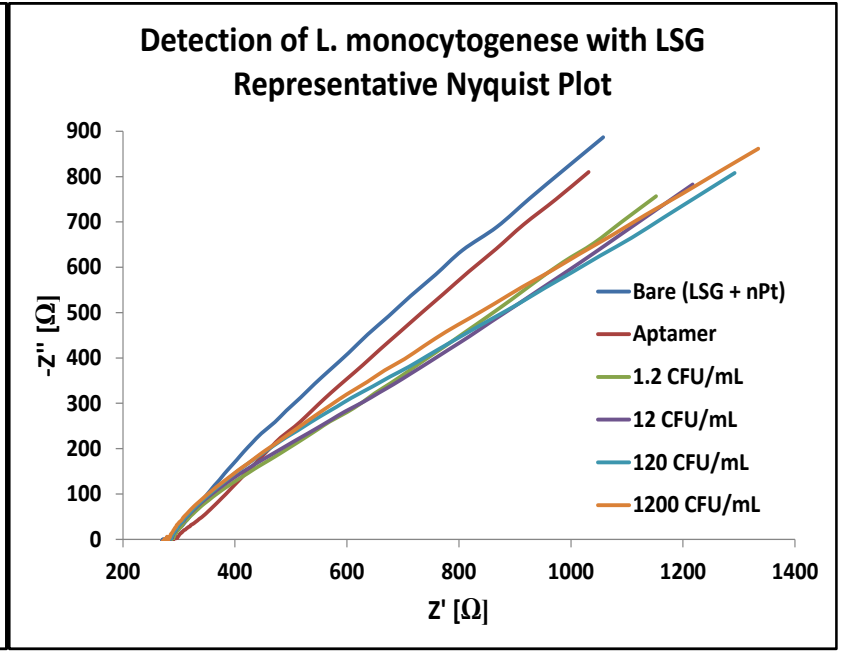

Representative Nyquist Plots Pulse Width Comparison
1600
1400
1200
1000
800
600
400
200
0
-Z'' [Ω]
0
2000
4000
6000
Z' [Ω]
10 ms
20 ms
30 ms
40 ms
50 ms

Shelf Life Study

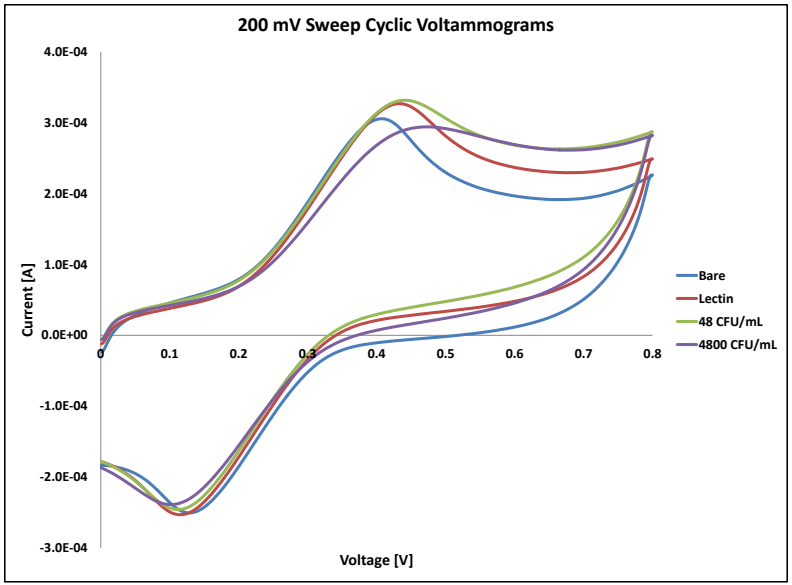


Preliminary Pathogen Detection

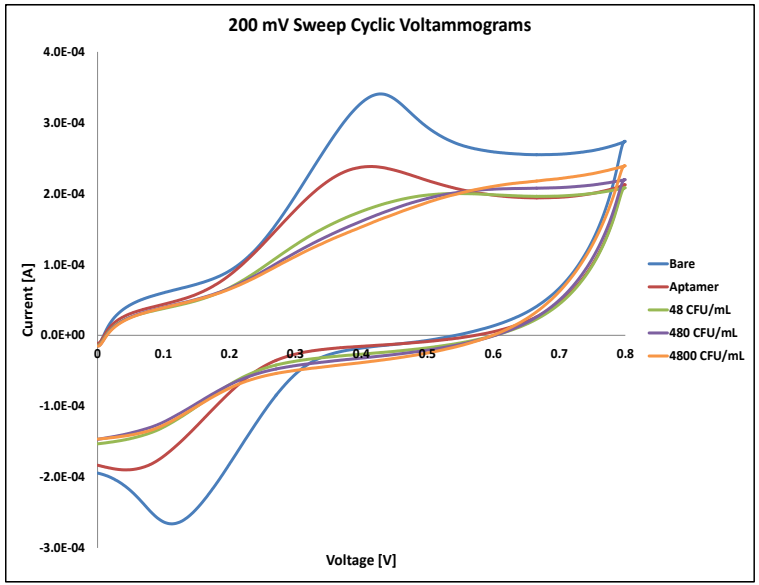




Easily Change the Target: *E. coli* Detection



Electrostatically Bound Lectin



Covalently Bound Aptamer

Vacuum Driven Flow Sensors

Develop and test a technique for *Listeria monocytogenes* detection in 225 mL samples, according to FDA standards, using vacuum driven flow through laser scribed graphene.

Objective Goal

- Vacuum processing of large sample volumes directly through porous graphene electrodes will allow for greater contact of *Listeria monocytogenes* cells with the biorecognition elements on the sensor surface and lead to increased detection capability.

Significance

- This study intends to develop a new technique for processing large sample volumes in biosensing.

Vacuum Driven Flow Throw LSG

- 225 mL Testing Volume
- Durability Testing with CV
- Flow Rate Determination
- Live Potential Measurements
- Sequential Testing: Bare LSG, nPt, Aptamer, Chitosan
- *L. monocytogenes* Detection

Broader Impacts

- Low cost methods for pathogen detection
- Increased sample volume processing
- Reduced pre-incubation time for microbial testing
- Reduced holding times and reduction of food waste
- Impacts beyond the food industry

Acknowledgements

Funding Sources:

- National Science Foundation Nanobiosensors Program (C. Gomes and E.S. McLamore; Project No. 1511953-Nanobioensing)
- United States Department of Agriculture (E.S. McLamore; Project No. 2018-68011-28374)

Undergraduate Assistants:

Ariel Terrand, Alyssa Bement, Zoë Davis, Enoch Kuo, Samantha Winther

Thank You For Your Time

Questions?