The Auburn University Detection and Food Safety Center: *Our Mission and Accomplishments*

AUBURN UNIVERSITY

DETECTION AND FOOD SAFETY CENTER

AUBURN UNIVERSITY PEAKS OF EXCELLENCE™

December 2010

Bryan A. Chin, Director

AUDFS is a multi-disciplinary, multi-college initiative.

Samuel Ginn
College of Engineering

College of Agriculture

College of Sciences and Mathematics

AUBURN UNIVERSITY

DETECTION AND FOOD SAFETY CENTER

College of Veterinary Medicine

College of Human Sciences

Research Team (Past and Present)

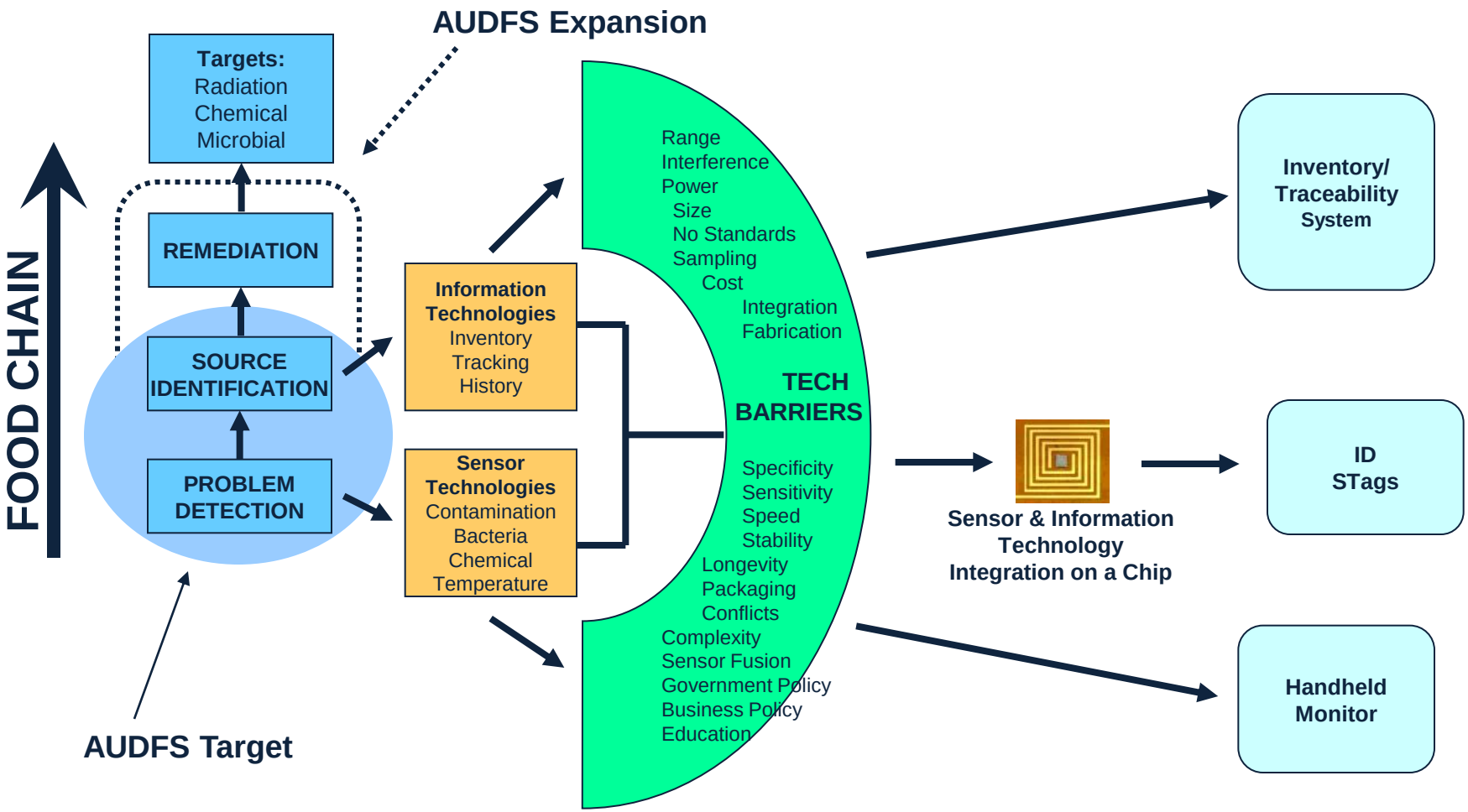
College of Agriculture	Donald E. Conner, Professor and Chair	HAACP, Sampling
	Jacek Wower, Professor	RNA/DNA
	Omar Oyarzabal, Associate Professor	Food Sample Preparation, Food Microbiology
	Manpreet Singh, Assistant Professor	Food Science, Microbiology
	Tung-Shi Huang, Assistant Professor	Antibody Development, Immobilization
	Jean Weese, Assoc. Professor/Ext. Food Specialist	Industrial Practices, Needs
Samuel Ginn College of Engineering	ZhongYang Cheng, Associate Professor	Polymers, Magnetostrictive Devices
	Bryan A. Chin, Professor and Chair	Bulk Food Monitor, Bacteria/Spore Binding
	Barton C. Prorok, Associate Professor	MEMs Design,M^3S Devices
	Dong-Joo (Daniel) Kim, Assistant Professor	MEMs Fabrication, Microcantilevers
	Aleksandr L. Simonian, Associate Professor	SPR, Bio-chemical recognition
	Jeffrey W. Fergus, Associate Professor	Carbon Dioxide Bacterial Sensing
	Jong Wook Hong, Assistant Professor	Microfluidic Devices
	Jin Wang, Assistant Professor	Statistical Probability
	William F. Gale, Professor	Education, Metal Surfaces/Bacteria Interaction
	Jeff Smith, Professor	Food/Plant Security
	Yonhua Tzeng, Professor	Microelectronics, Thin films
	Mark Byrne, Associate Professor	Kinetics, Polymer Membranes, Drug Delivery
College of Human Sciences	Hae-jung An, Assistant Professor	Food Science, Sampling
	Peggy Hsieh, Professor	Test Kits, Food Species Determination
	Cheng-I Wei, Professor	Food Science, Food Microbiology
College of Sciences and Mathematics	William Charles Neely, Professor	Air/Liquid Extraction, Chemical Binding
	Curtis Shannon, Assoc. Professor	Self Molecular Assembly
	James M. Barbaree, Professor	Microbiology, Bacteria, Spores
	Minseo Park, Assistant Professor	Raman Spectroscopy
	Sang-Jin Suh, Assistant Professor	Phage Development
	Wei Zhan, Assistant Professor	Biosensors, Chemical Detection
	Laura Suh, Assistant Professor	Spores, Food Safety
	Robert Locy, Professor	Plant Biochemistry, Signal Transduction
	An-Ban Chen, Professor	Modeling
	David Held, Assistant Professor	Food/Plant Security
College of Veterinary Medicine	Vitaly Vodyanoy, Professor	Molecular Recognition, Immobilization
	Valery A. Petrenko, Professor	Bio-molecular Recognition, Phage
	Arnold Vainrub, Associate Professor	Bio-molecular Recognition, DNA

Auburn University
Detection and Food Safety Center

Our vision is to improve the safety of the U.S. food system by developing the science and engineering required to rapidly identify, pinpoint and characterize problems that arise in the food supply chain through the integration of sensor and information systems technology.

www.auburn.edu/audfs

AUDFS Focus


AUDFS Expansion
Targets:
Radiation
Chemical
Microbial
REMEDIATION
SOURCE IDENTIFICATION
PROBLEM DETECTION
FOOD CHAIN
AUDFS Target
Information Technologies
Inventory
Tracking
History
Sensor Technologies
Contamination
Bacteria
Chemical
Temperature
Range
Interference
Power
Size
No Standards
Sampling
Cost
Integration
Fabrication
TECH BARRIERS
Specificity
Sensitivity
Speed
Stability
Longevity
Packaging
Conflicts
Complexity
Sensor Fusion
Government Policy
Business Policy
Education
Inventory/ Traceability System
Sensor & Information Technology Integration on a Chip
ID STags
Handheld Monitor

AUDFS Annual Assessment

	2004	2005	2006	2007	2008	2009	2010
Publications (Refereed Pubs) (cumulative)	132	152	181	239	285	324	354
Students, Staff, Research Assoc. supported (annual)	55	56	112	54	66	59	54
M.S. Graduates (cumulative)	28	38	44	46	48	57	61
Ph.D. Graduates (cumulative)	23	34	39	42	54	67	74
Patents	9	10	15	19	19	20	
Disclosures	36	54	89	109	113	119	133
Commercialized Products	3	4	4	5	6	6	6

Commercialized Technologies

	2004	2005	2006	2007	2008	2009	2010
Disclosures (cumulative)	36	54	89	109	113	119	133
Patents Awarded (cumulative)	9	10	15	19	19	20	
Commercialized Technology (cumulative)	3	4	4	5	6	6	6

Raytheon RFID Bulk STag for Patriot Missile Health Monitoring Mil Spec Qualified

Meat species identification technology licessed to ELISA Technologies

RMBM in livestock feed identification technology licensed to Neogen Corp.

Optical microscope technology licensed to Aetos Technologies, Inc.

Canine Olfactory Measurement Method licensed to RedXDefense, Inc.

Requirements of AUDFS Participants

- Two refereed journal publications per year
- One AUDFS PhD graduate every 5 years
- Use AUDFS funding to gather preliminary data for grant application
- One externally funded grant every three years that exceeds AUDFS cumulative funding by 4 times

Spinoff Center: FAA Center of Excellence for Airliner Cabin Environment Research (ACER)

- 8th institution center with AU as Administrative Lead
- $3.5 M from FAA in first year of operation
- 1:1 matching by industry & member universities
- 26 industry partners & growing
- Major focus on chem.–bio. sensing aboard airliners
  - Cross-membership between AUDFS and ACER teams
  - ACER is implementing technologies developed by AUDFS
  - ACER is bringing new industry partners to AUDFS
- ACER is now part of the new National Center of Excellence for Research in the Intermodal Transport Environment (RITE)

Spinoff Project: Condition Based Maintenance for Military Vehicles

Contract: $1 million/year

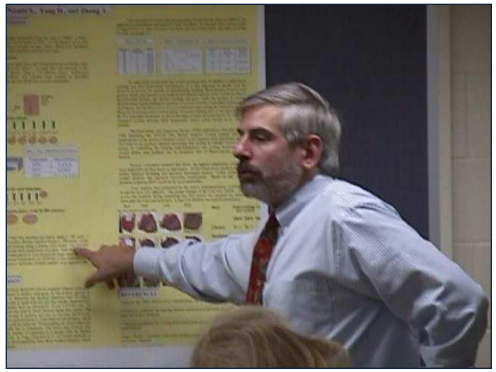
Sponsored by FTI Inc. through the U.S. Army TACOM CBM

- **Project will produce a universal vehicle condition monitoring system based on AUDFS-developed technologies (shipment and plant monitoring system) that enables predictive and proactive maintenance**
- **Employs sensor concepts and data acquisition/recording hardware developed by AUDFS to monitor critical parameters related to vehicle condition and reliability**
- **Project seeks to reduce maintenance costs and provide early warning of impending failures of expensive battle equipment, affording soldiers better protection from terrorists and enemy fighters**
- **Works toward implementation of a microscale device to monitor engine oil conditions in a “smart dipstick”**

Cross-disciplinary Food Science-Engineering Course

- Over $1 Million in Funded Education Projects (USDA & NSF)
- Streaming Video and DVD for Off-Campus Students
- Food Safety/Production Practitioners
- Credit for Certification and Advanced Degrees

Profs. Bill Gale & Jeff Fergus



Profs. Don Conner & Omar Oyarzabal

AUDFS TECHNOLOGIES

Ongoing AUDFS Investigations

- RNA-based biosensors for pathogen detection
- New biodetection method using amplified photo electrochemical signaling
- Air sampling for *E. coli* detection on spinach leaves
- Chemical sensing strategies based on molecularly imprinted polymers
- Wireless amperometric sensors for pathogen detection
- FET DNA biosensors for pathogen detection
- Improvement of phage probes using genetic engineering
- Phage for MRSA detection
- Immobilizing phage using Langmuir-Blodgett Films
- Surface modification of ME materials to allow direct immobilization of phage
- Liquid phage solutions for cleaning of food preparation surfaces
- Vortex Centrifuges for detection of contamination in large volumes of food
- Invasive insect species detection using Smart automated traps
- Magnetoelastic sensors for pathogen detection on fresh fruits/vegetables
- Magnetoelastic sensors for in-situ monitoring of plant physiology

Phage-based Magnetoelastic Biosensor

Landscape Phage **as Bio-receptor**

Magnetoelastic Particle **as Sensor Platform**

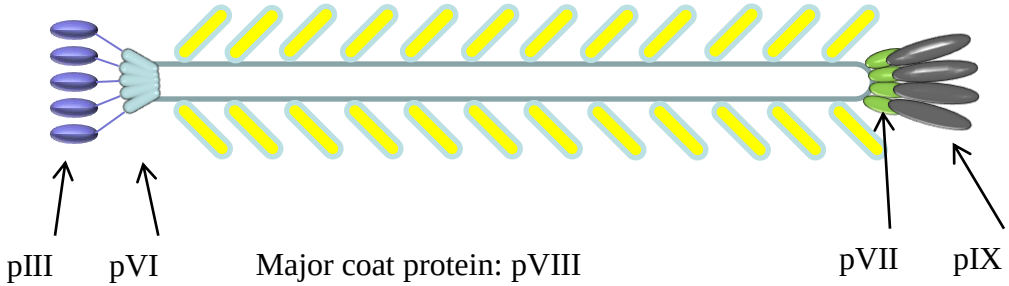
JRB7 Phage against ***Bacillus anthracis***

E2 Phage against ***Salmonella typhimurium***

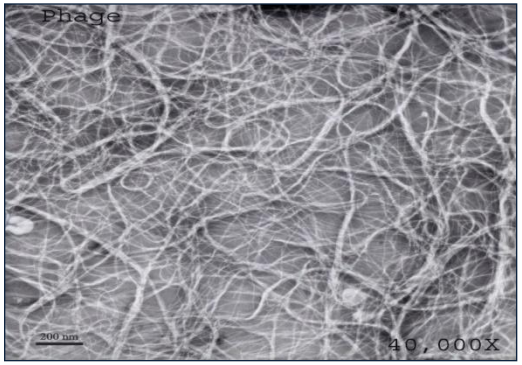
Biomolecular Recognition

Filamentous Phage

- Virus-like agents that infect bacteria
- Investigating filamentous phages including M13, f1 and f3
- Approximately 7nm diameter and 900 nm long
- Genetically engineered coat proteins for specificity



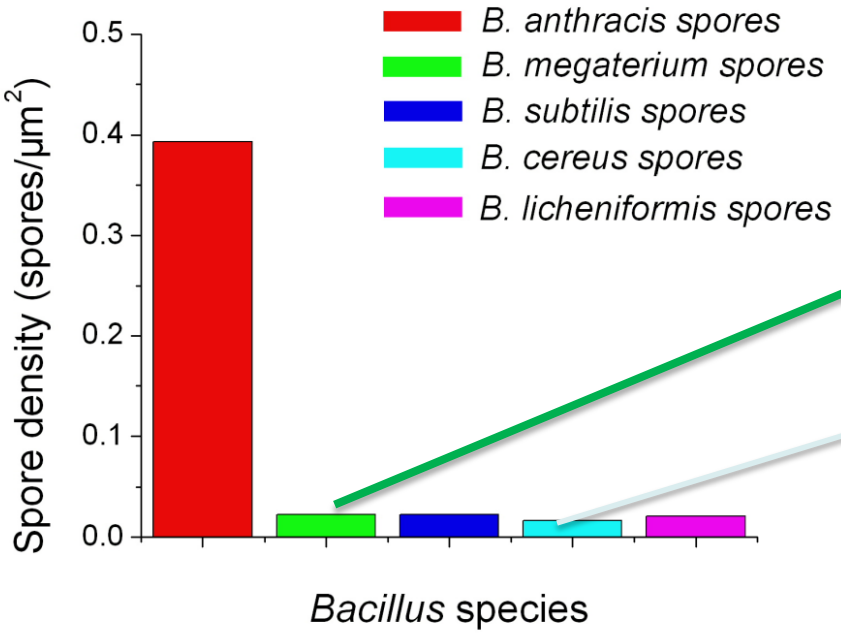
TEM micrographs

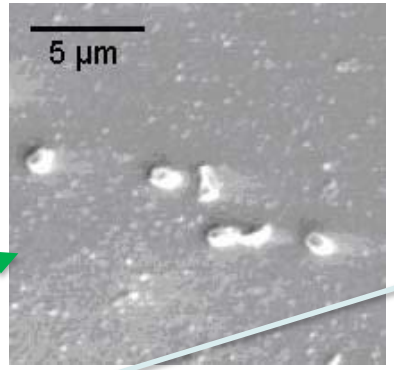


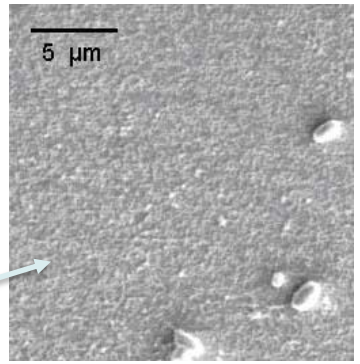
AUDFS Patents

- *Bacillus anthracis* phage
- *Salmonella* phage

Specificity of *B. Anthracis* Phage







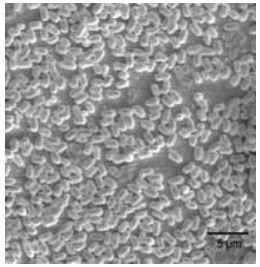
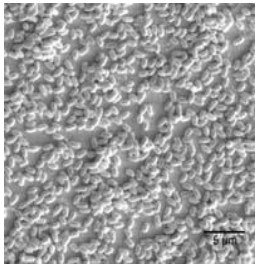
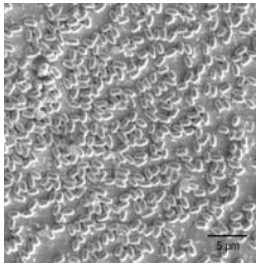
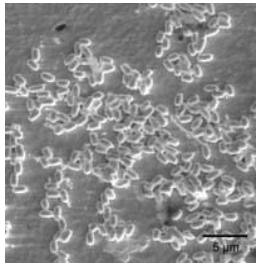
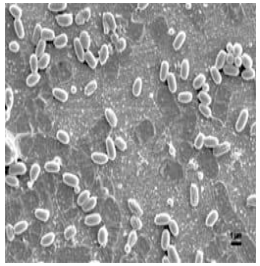
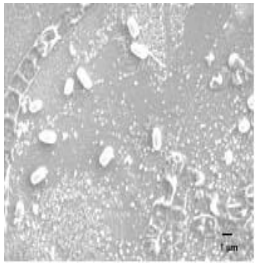
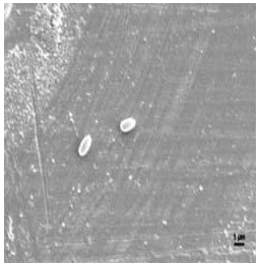
It is impossible to distinguish between the species optically.

***Bacillus Anthracis* Spores bound phage-coated magnetoelastic sensors**

- **40-fold better than *B. licheniformis* and *B. megaterium***
- **15-fold better than *B. subtilis* and *B. cereus* spores.**

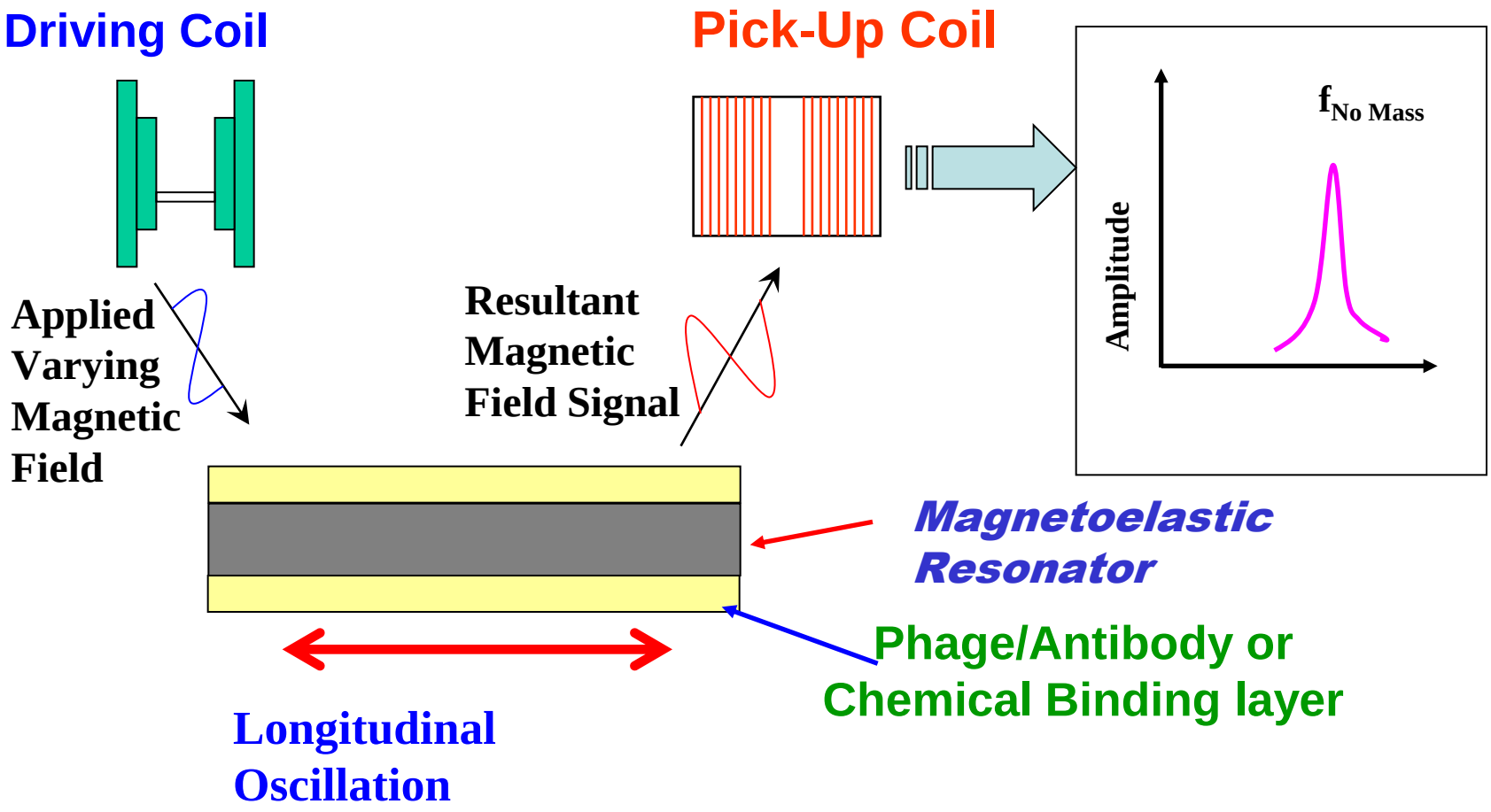
Longevity of Phage-coated Sensors

The SEM images of phage-coated sensors and antibody-coated sensors at 65°C

	Day 0	Day 3	Day 5	Day 63
Phage-coated sensor at 65°C				
Antibody-coated sensor at 65°C				**No spore binding**

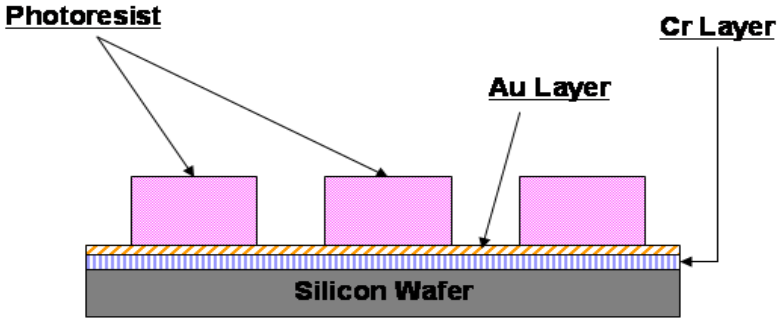
- **The binding activity of antibody-coated biosensor dropped to zero after storage at 65°C for 5 days.**
- **Phage-coated biosensors still showed good binding affinity after two months.**

Magnetoelastic Particle Sensor

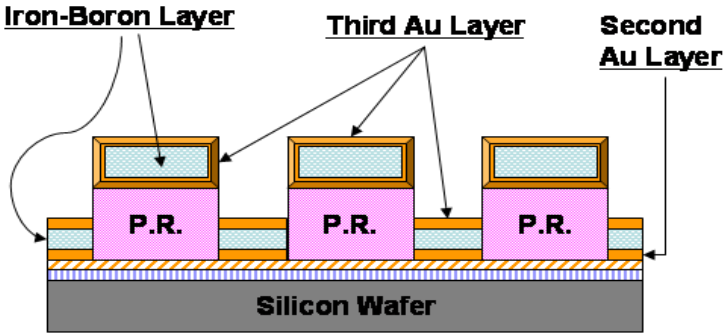


Fabrication of Magnetoelastic Sensors

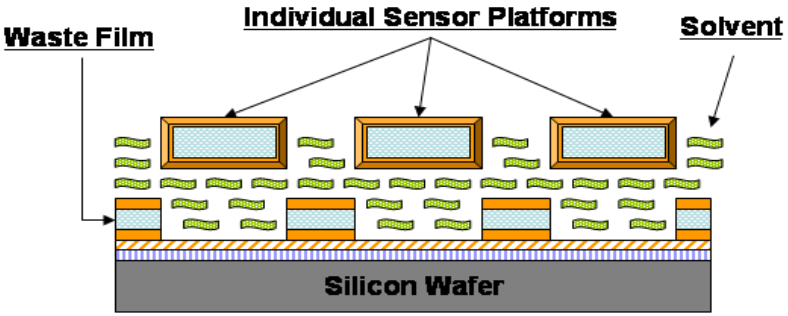
1. Patterning of the chromium and gold coated silicon wafer.

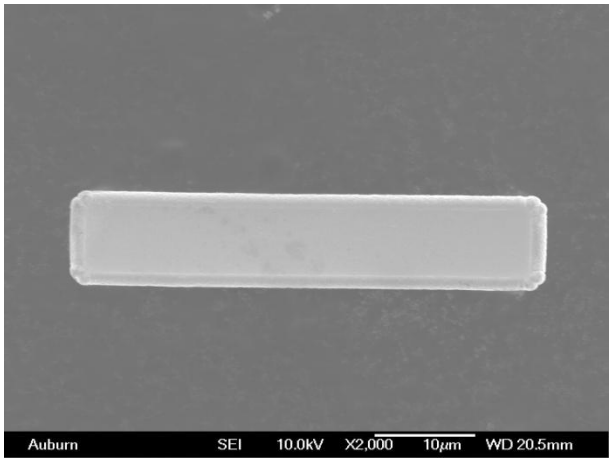


2. Deposition of a second gold layer, the magnetoelastic iron-boron layer, and finally a top gold layer.



3. Lift-off of the particles is performed by dissolving the photoresist with a solvent, leaving the surrounding waste film on the wafer.





4 x 10 x 50 μm Sensor Capable of Detecting a Few Spores

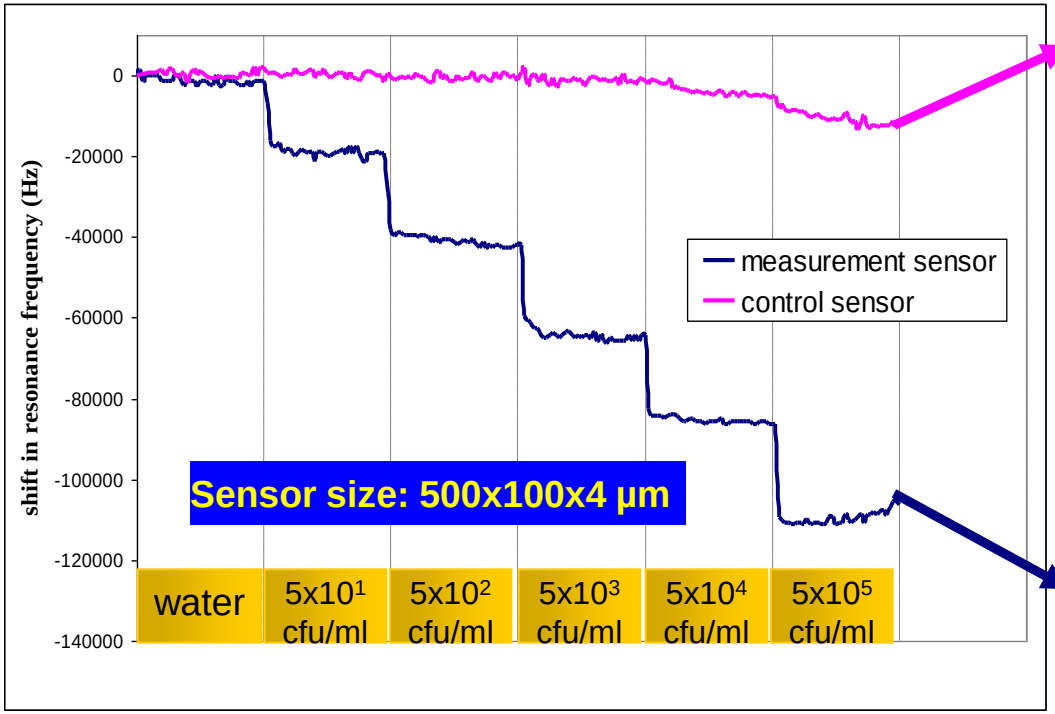
Size of the ME Biosensor

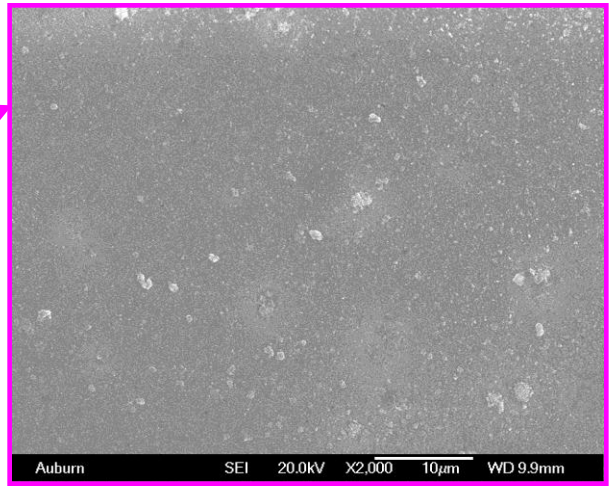
Scanning Electron Micrograph comparing the size of a ME biosensor with the Y in "LIBERTY" on a penny.

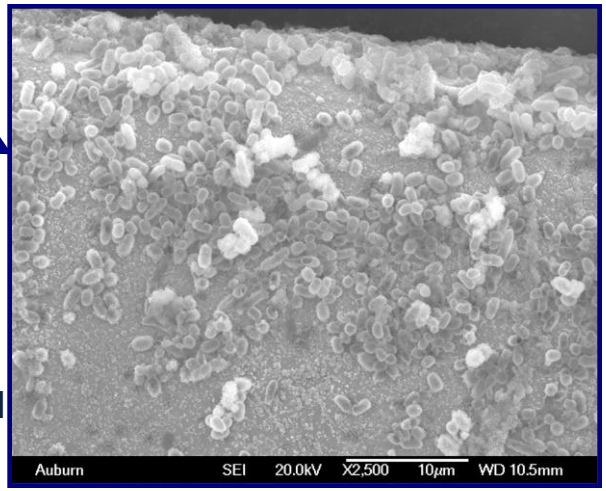
The biosensors are microelectronically fabricated and are smaller than a particle of dust.

The biosensors require no on-board power and their cost is less than 1/1000 of a cent each when fabricated in large numbers.

Response of 500 micron long biosensor exposed to increasingly higher concentrations of *Salmonella*



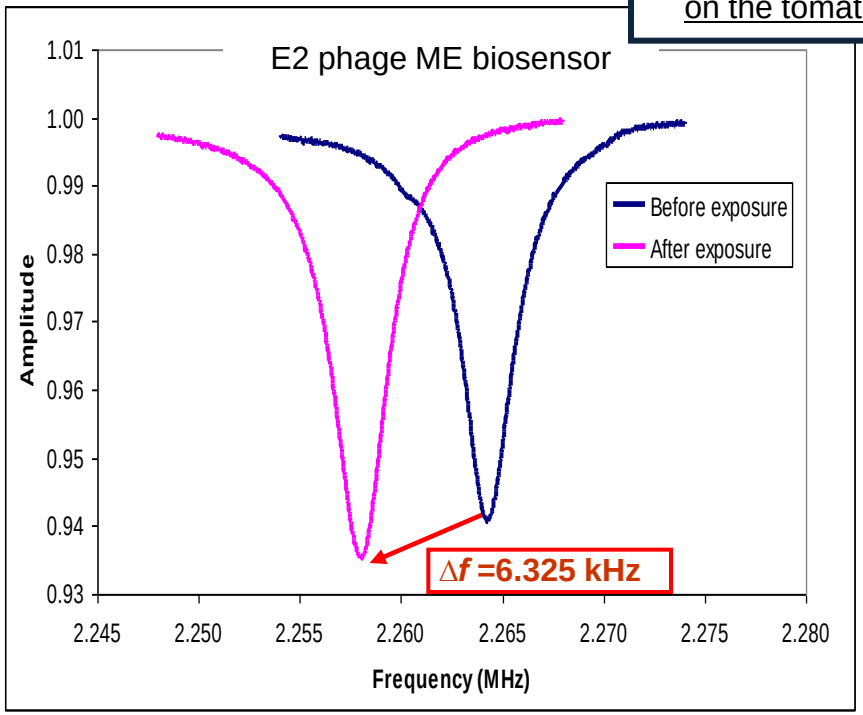


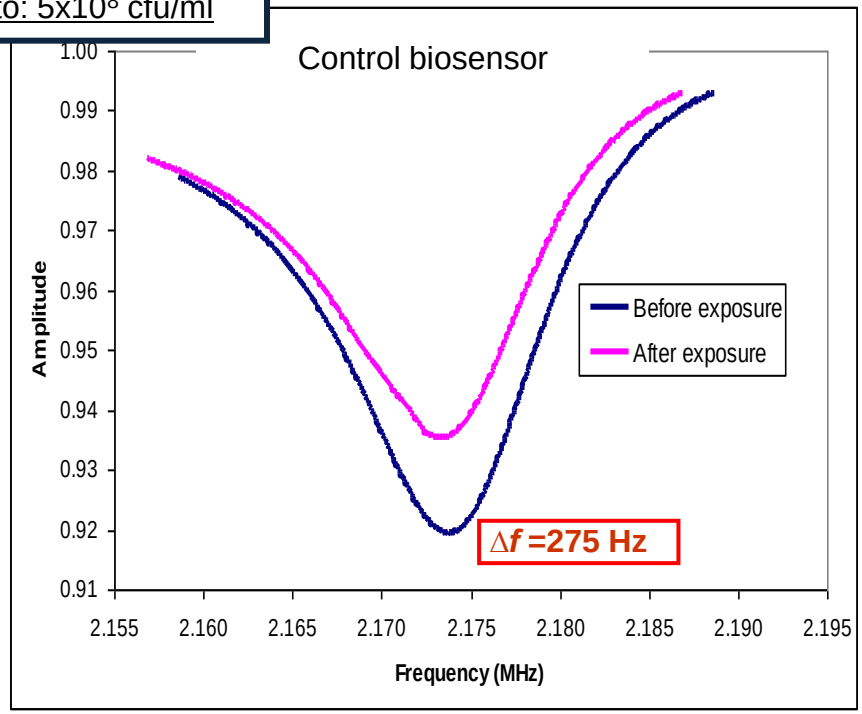


Detection limit better than 50 CFU/ml. The response of the control sensor (devoid of phage) is also shown. The SEM images show near zero binding of *Salmonella* cells to the control sensor and a large number of bound *Salmonella* cells to the measurement sensor.

S. typhimurium Detection on Tomato Surface

S. *Typhimurium* concentration on the tomato: 5x10^8 cfu/ml



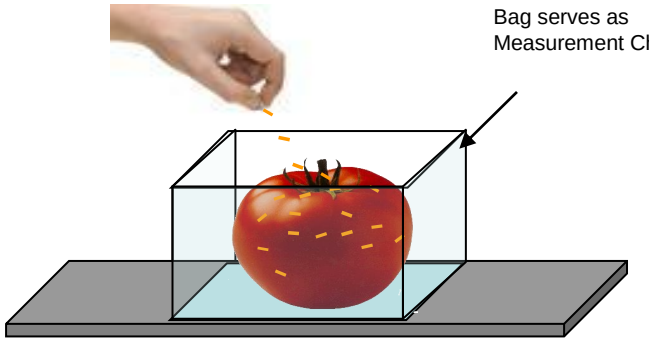


Resonance Frequencies of Control and Measurement Bioensors

After Exposure to Tomato Spiked with *S. typhimurium* (5x10^8 cfu/mL)

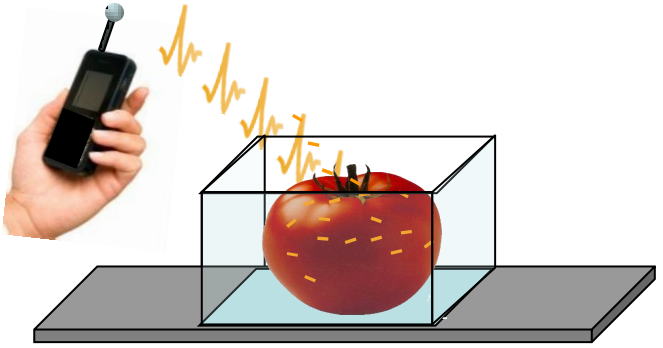
Vision of Direct Bacterial Detection on Foods

1 Distribute Sensors (1 minute)



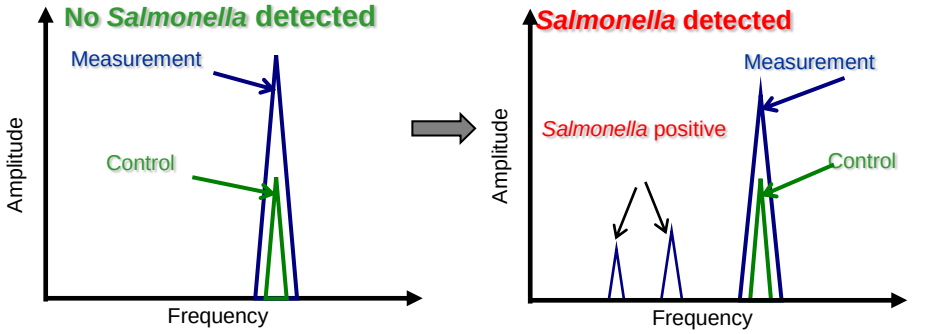
Sprinkle 55 sensors (50 measurement, 5 control) onto the tomato, wait 1 minute for binding to occur.

2 Measure (< 1 minute)



Measure wirelessly and simultaneously the 55 sensors. Less than 1 minute.

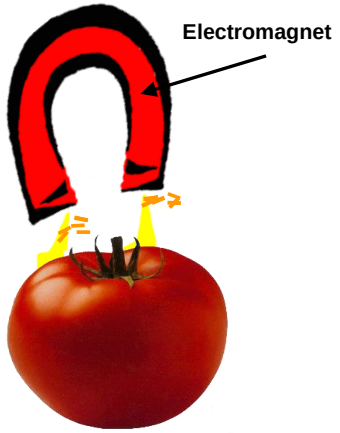
3 Analyze Data (< 1 minute)



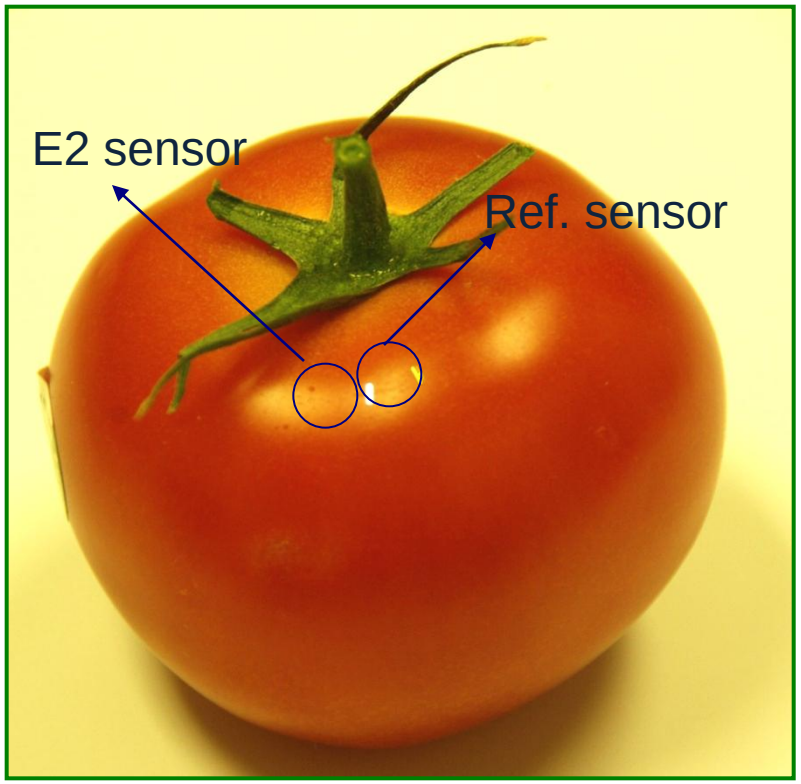
If control and measurement sensors show same resonance frequency, then an undetectable amount of *Salmonella* is present.

If peaks appear below control, then have positive *Salmonella* contamination.

4 Retrieve Sensors (< 1 minute)



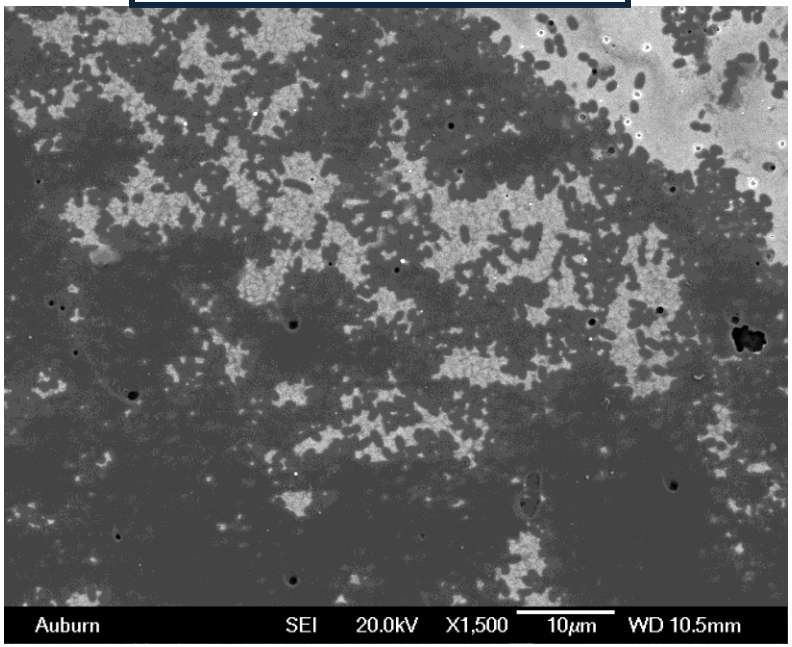
S. typhimurium Detection on Tomato Surface



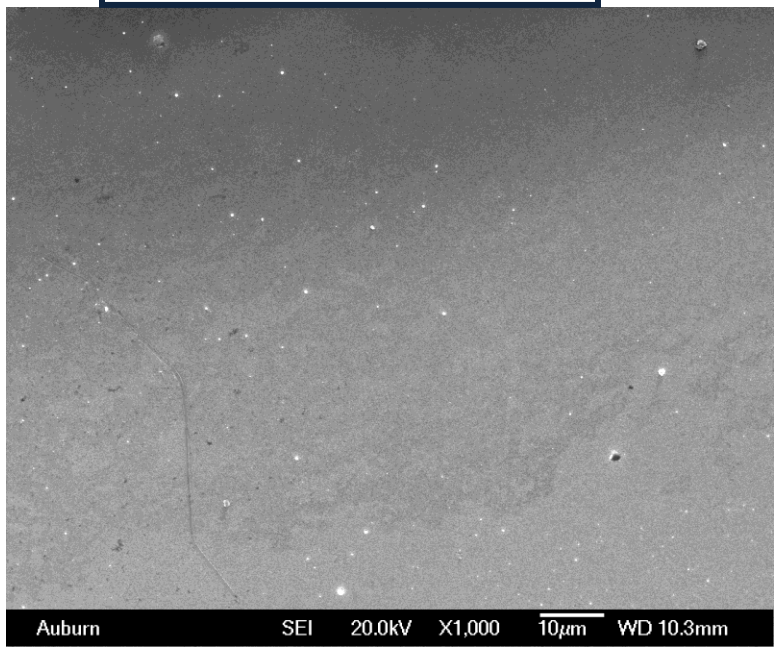
Fresh tomato → Put 20µl *S. typhimurium* suspension and let it dry in air → Place E2 phage-coated ME biosensor on the dried tomato for 30 mins at 85% humidity

S. typhimurium Detection on Tomato Surface

Measurement Biosensor



Control sensor



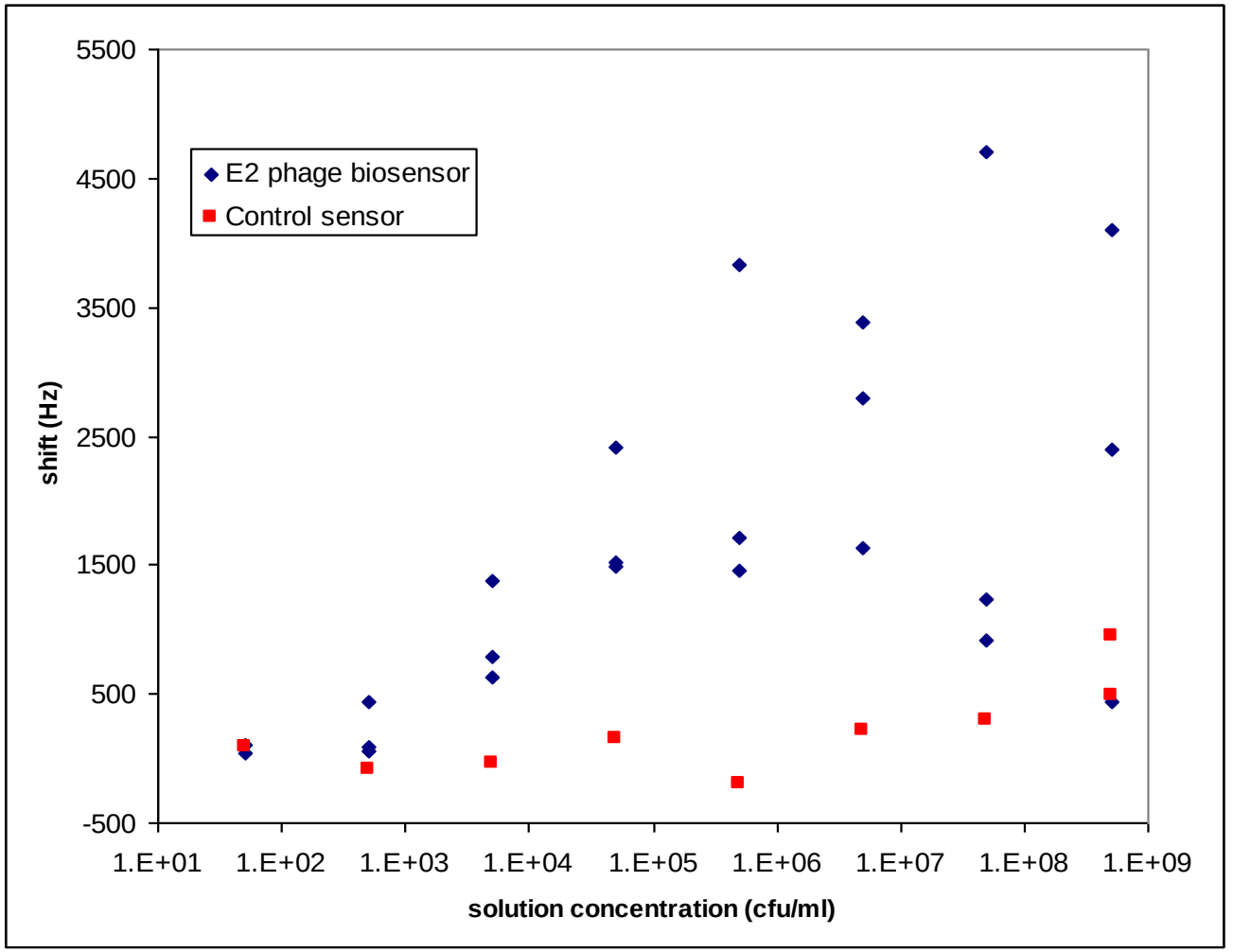
Surface of Control and Measurement Bioensors

After Exposure to Tomato Spiked with *S. typhimurium* ($5x10^8$ cfu/mL)

Statistical Response of *S. typhimurium* Detection on Tomato Surface

Sensor size:
1000 x 200 x 28 µm

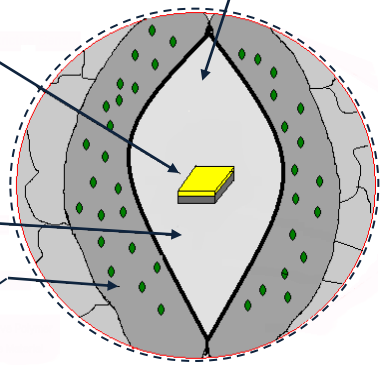
Each data point is the average of three sensors.



Internal Plant Growth Monitor

Plant Stoma

Magnetoelastic Sensor
- — Temperature
- — Humidity
- — Ion Concentration
- — Osmotic Pressure

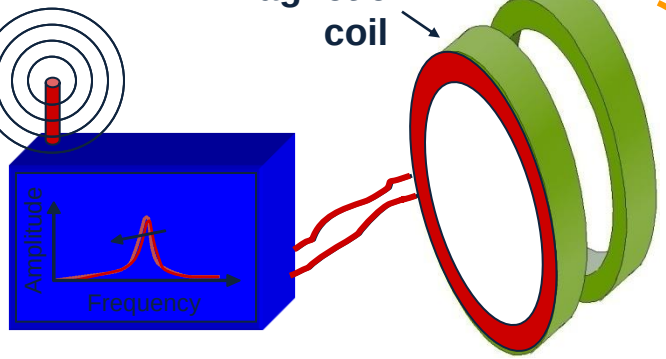


Stomatal Pore

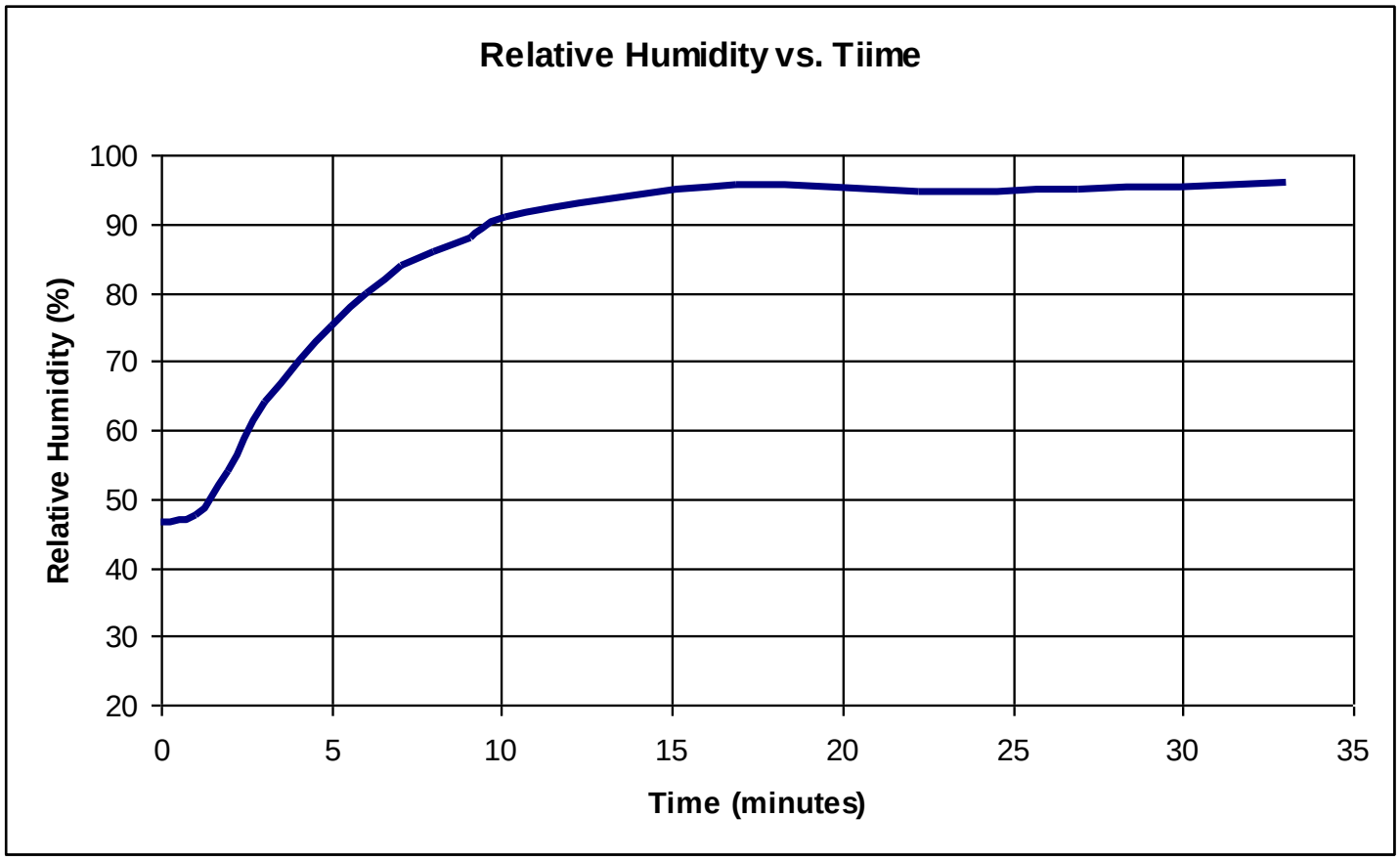
Guard Cell

Processing Electronics and Transceiver

Magnetic coil



Internal Cavity Humidity as Measured by Magnetoelastic Sensor



Questions?

Funded by:

United States Department of Agriculture

National Institute of Food and Agriculture