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

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

College of Veterinary Medicine

College of Human Sciences
<table>
<thead>
<tr>
<th>College of Agriculture</th>
<th>Research Team (Past and Present)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Donald E. Conner, Professor and Chair</td>
<td>HAACP, Sampling</td>
</tr>
<tr>
<td>Jacek Wower, Professor</td>
<td>RNA/DNA</td>
</tr>
<tr>
<td>Omar Oyarzabal, Associate Professor</td>
<td>Food Sample Preparation, Food Microbiology</td>
</tr>
<tr>
<td>Manpreet Singh, Assistant Professor</td>
<td>Food Science, Microbiology</td>
</tr>
<tr>
<td>Tung-Shi Huang, Assistant Professor</td>
<td>Antibody Development, Immobilization</td>
</tr>
<tr>
<td>Jean Weese, Assoc. Professor/Ext. Food Specialist</td>
<td>Industrial Practices, Needs</td>
</tr>
<tr>
<td>ZhongYang Cheng, Associate Professor</td>
<td>Polymers, Magnetostrictive Devices</td>
</tr>
<tr>
<td>Bryan A. Chin, Professor and Chair</td>
<td>Bulk Food Monitor, Bacteria/Spore Binding</td>
</tr>
<tr>
<td>Barton C. Prorok, Associate Professor</td>
<td>MEMs Design, M⁶S Devices</td>
</tr>
<tr>
<td>Dong-Joo (Daniel) Kim, Assistant Professor</td>
<td>MEMs Fabrication, Microcantilevers</td>
</tr>
<tr>
<td>Aleksandr L. Simonian, Associate Professor</td>
<td>SPR, Bio-chemical recognition</td>
</tr>
<tr>
<td>Jeffrey W. Fergus, Associate Professor</td>
<td>Carbon Dioxide Bacterial Sensing</td>
</tr>
<tr>
<td>Jong Wook Hong, Assistant Professor</td>
<td>Microfluidic Devices</td>
</tr>
<tr>
<td>Jin Wang, Assistant Professor</td>
<td>Statistical Probability</td>
</tr>
<tr>
<td>William F. Gale, Professor</td>
<td>Education, Metal Surfaces/Bacteria Interaction</td>
</tr>
<tr>
<td>Jeff Smith, Professor</td>
<td>Food/Plant Security</td>
</tr>
<tr>
<td>Yonhwa Tzeng, Professor</td>
<td>Microelectronics, Thin films</td>
</tr>
<tr>
<td>Mark Byrne, Associate Professor</td>
<td>Kinetics, Polymer Membranes, Drug Delivery</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Samuel Ginn College of Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hae-jung An, Assistant Professor</td>
</tr>
<tr>
<td>Peggy Hsieh, Professor</td>
</tr>
<tr>
<td>Cheng-I Wei, Professor</td>
</tr>
<tr>
<td>William Charles Neely, Professor</td>
</tr>
<tr>
<td>Curtis Shannon, Assoc. Professor</td>
</tr>
<tr>
<td>James M. Barbaree, Professor</td>
</tr>
<tr>
<td>Minseo Park, Assistant Professor</td>
</tr>
<tr>
<td>Sang-Jin Suh, Assistant Professor</td>
</tr>
<tr>
<td>Wei Zhan, Assistant Professor</td>
</tr>
<tr>
<td>Laura Suh, Assistant Professor</td>
</tr>
<tr>
<td>Robert Locy, Professor</td>
</tr>
<tr>
<td>An-Ban Chen, Professor</td>
</tr>
<tr>
<td>David Held, Assistant Professor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>College of Human Sciences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitaly Vodyanoy, Professor</td>
</tr>
<tr>
<td>Valery A. Petrenko, Professor</td>
</tr>
<tr>
<td>Arnold Vainrub, Associate Professor</td>
</tr>
</tbody>
</table>
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

Targets: Radiation, Chemical, Microbial

REMEDICATION

SOURCE IDENTIFICATION

PROBLEM DETECTION

AUDFS Target

AUDFS Expansion

Information Technologies
- Inventory
- Tracking
- History

Sensor Technologies
- Contamination
- Bacteria
- Chemical
- Temperature

TECH BARRIERS
- Range
- Interference
- Power
- Size
- No Standards
- Sampling
- Cost
- Integration
- Fabrication
- Specificity
- Sensitivity
- Speed
- Stability
- Longevity
- Packaging
- Conflicts
- Complexity
- Sensor Fusion
- Government Policy
- Business Policy
- Education

Sensor & Information Technology Integration on a Chip

Inventory/Traceability System

ID STags

Handheld Monitor

TARGETS: Radiation, Chemical, Microbial

FOOD CHAIN
# AUDFS Annual Assessment

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

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disclosures (cumulative)</td>
<td>36</td>
<td>54</td>
<td>89</td>
<td>109</td>
<td>113</td>
<td>119</td>
<td>133</td>
</tr>
<tr>
<td>Patents Awarded (cumulative)</td>
<td>9</td>
<td>10</td>
<td>15</td>
<td>19</td>
<td>19</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Commercialized Technology (cumulative)</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

- **Raytheon RFID Bulk STag for Patriot Missile Health Monitoring Mil Spec Qualified**
- **Meat species identification technology licensed 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

- 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”.

Contract: $1 million/year
Sponsored by FTI Inc. through the U.S. Army TACOM CBM
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

*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.

It is impossible to distinguish between the species optically.
Longevity of Phage-coated Sensors

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

Driving Coil

Applied Varying Magnetic Field

Magnetoelastic Resonator

Longitudinal Oscillation

Pick-Up Coil

Resultant Magnetic Field Signal

Phage/Antibody or Chemical Binding layer

Amplitude vs. Frequency

$f_{\text{No Mass}}$
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

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)
   - Bag serves as Measurement Chamber
   - 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)
   - Electromagnet
**S. typhimurium** Detection on Tomato Surface

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

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

Magnetoelectric Sensor
- Temperature
- Humidity
- Ion Concentration
- Osmotic Pressure

Stomatal Pore
Guard Cell

Processing Electronics and Transceiver

Plant Stoma

Magnetic coil

Frequency

Auburn University
Internal Cavity Humidity as Measured by Magnetoelastic Sensor

Relative Humidity vs. Time

Time (minutes)

Relative Humidity (%)
Questions?

Funded by:

United States Department of Agriculture

National Institute of Food and Agriculture