Land Based Agricultural Sensors and Sensor Networks Today, Tomorrow and Beyond

AUBURN

DETECTION AND FOOD SAFETY CENTER

April 24, 2007

AUBURN UNIVERSITY PEAKS OF EXCELLENCE™

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AUDFS is a multi-disciplinary, multi-college initiative with "Peak of Excellence" status.

Agriculture

Engineering

Sciences & Mathematics

Veterinary Medicine

Human Sciences

Commercialized Technologies

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Disclosures & Patents	3	12	10	25	31	103
Commercialized Products	0	0	1	3	4	6

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.

Current Technologies

Pear Orchard

NE 10 acres

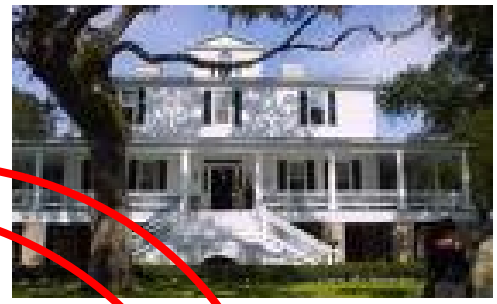
Grape Vineyard

North 50 acres

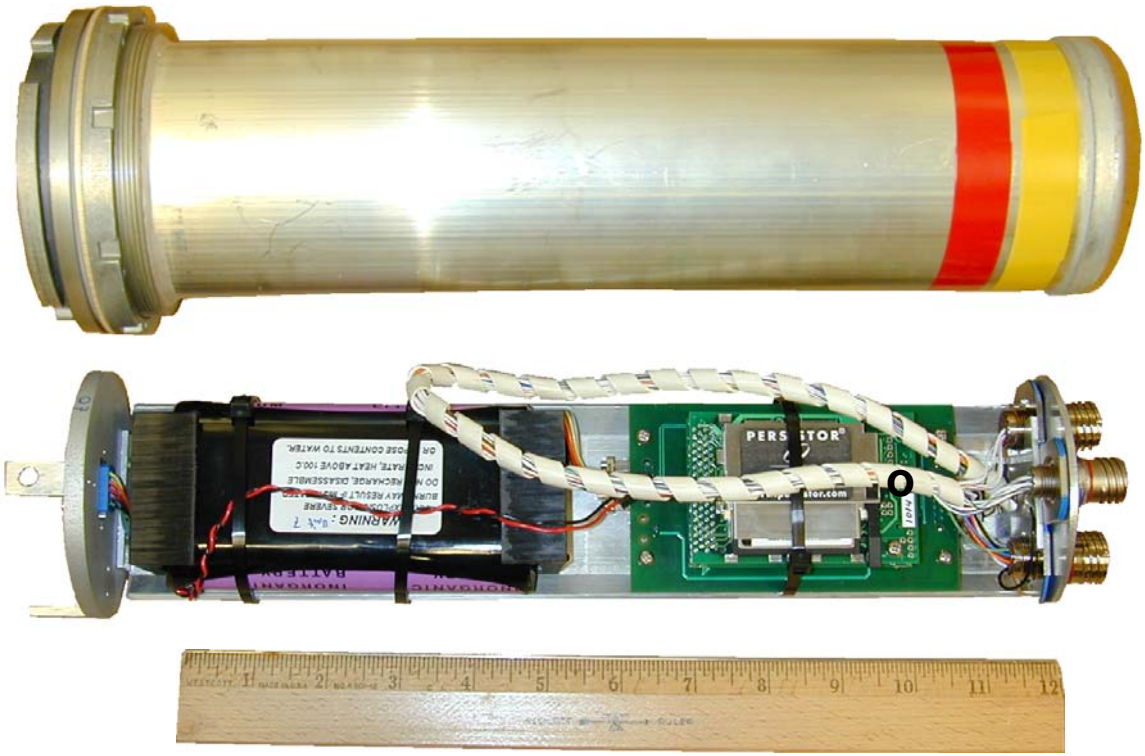
Apple Orchard

East 40 acres

Available to all



RFID Patriot Missile Health Monitoring Unit



Key: Communicate Data to Commercial Net (cell phone) to provide robustness, economies of scale and multitude of vendors.

Monitors

- **Temperature (-55 to 175˚F)**
- **Humidity (0-99% condensing)**
- **Shock & vibration**
- **Up to 24 other sensors**

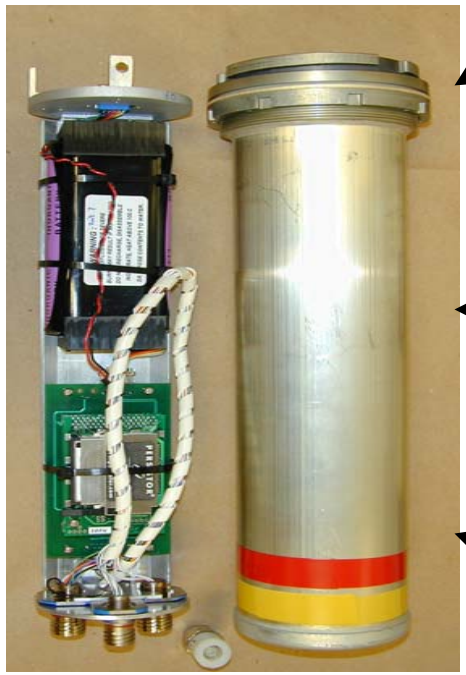
Performance

- **Time variable sensor measurements**
- **Auto alarm for out of spec conditions**
- **Daily or timed RF transfer of data**
- **8 years of life from batteries**

Sensor Availability

Current

- Air
  - Temperature
  - Humidity
  - Wind
  - Barometric Pressure
  - CO_2
- Soil
  - Temperature
  - Moisture
  - pH
- Light
  - Intensity
  - Wavelength Distribution
- Water
  - Runoff



Short Term

- Ripeness
- Mold

Medium Term

- Fecal Runoff
- Insect Infestation
- Chemicals
- Pesticides

Long Term

- Bacterial
  - E. Coli
  - Salmonella

Future Sensors, Its all about size!

Conventional Sensors

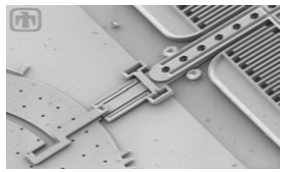
Miniaturized Sensors

Micro Sensors

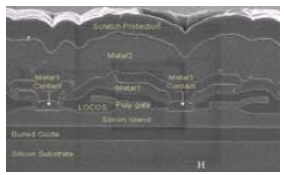
Nano Sensors

Conventional Components

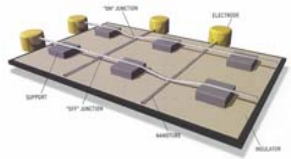
MEMS



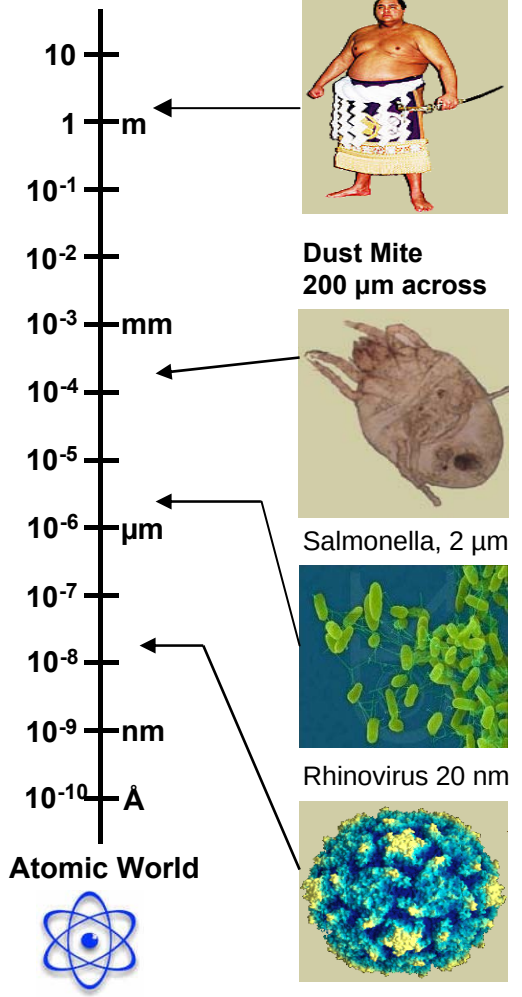
Microelectronics and Thin Films



Nano - Devices



Size Scale



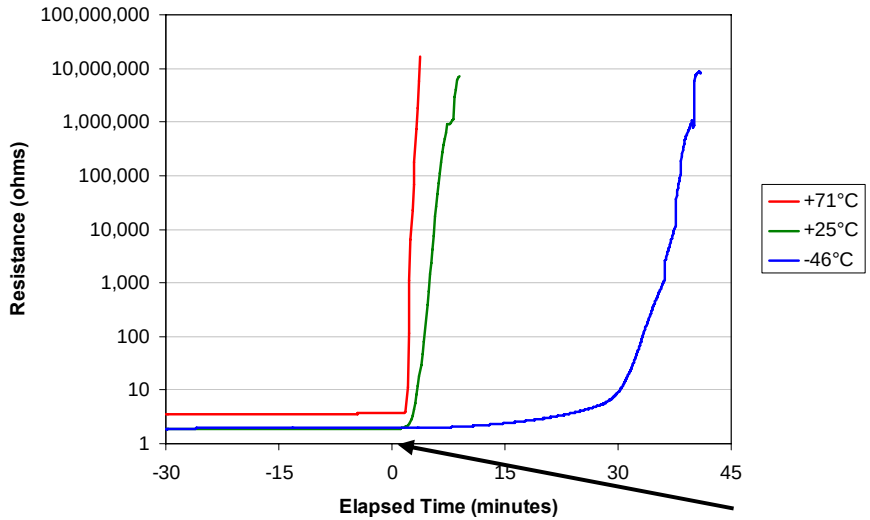
Miniaturized Sensors

Herbivore attack

Insect Infestation Detection

Conducting Polymer Sensor Response

Terpenoid Detection



Gas Introduction 100 ppb @ .25 L/min

Herbivore attack

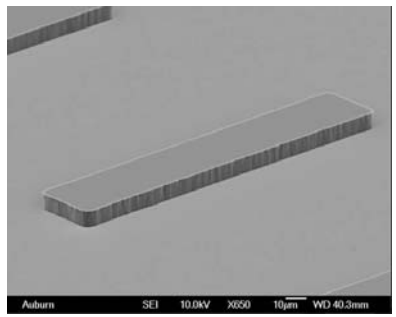
Specific Response

- Isoprenoid-derived terpenoids
- Shikimic acid-derived aromatics
- Lipoxygenase-derived green leaf volatiles

Micro Sensors

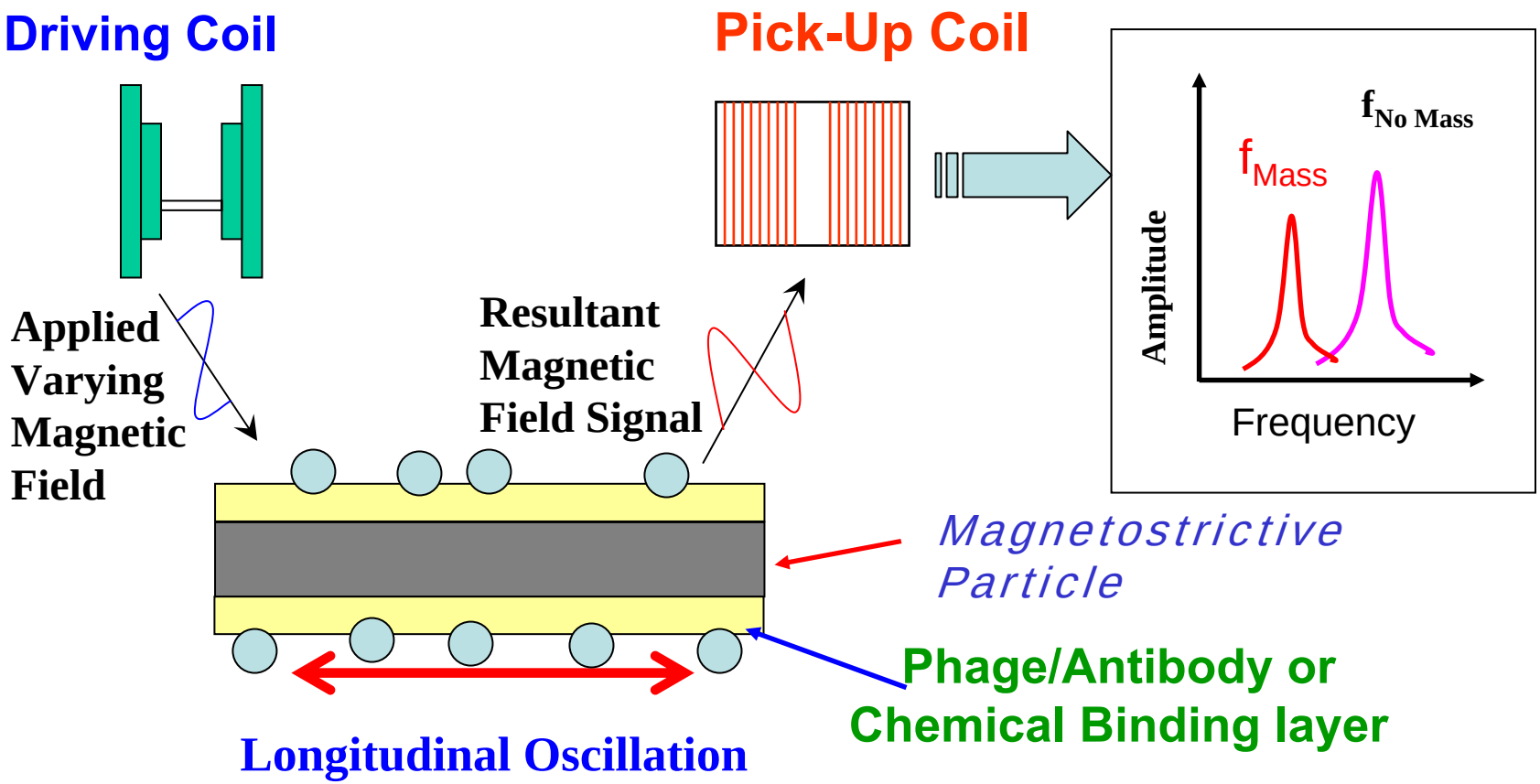
Internal Plant Monitoring

Stoma

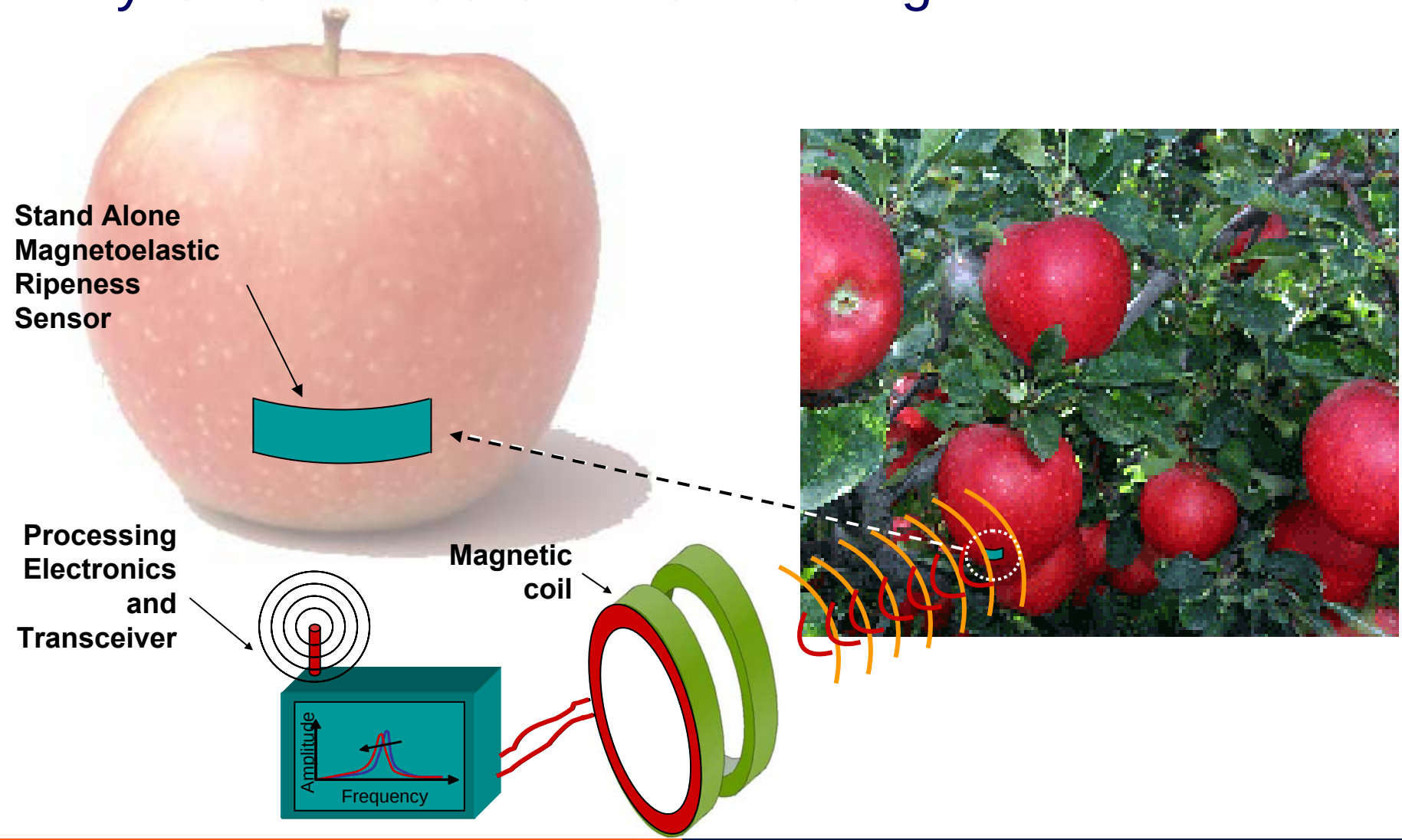


Magnetostrictive Sensor

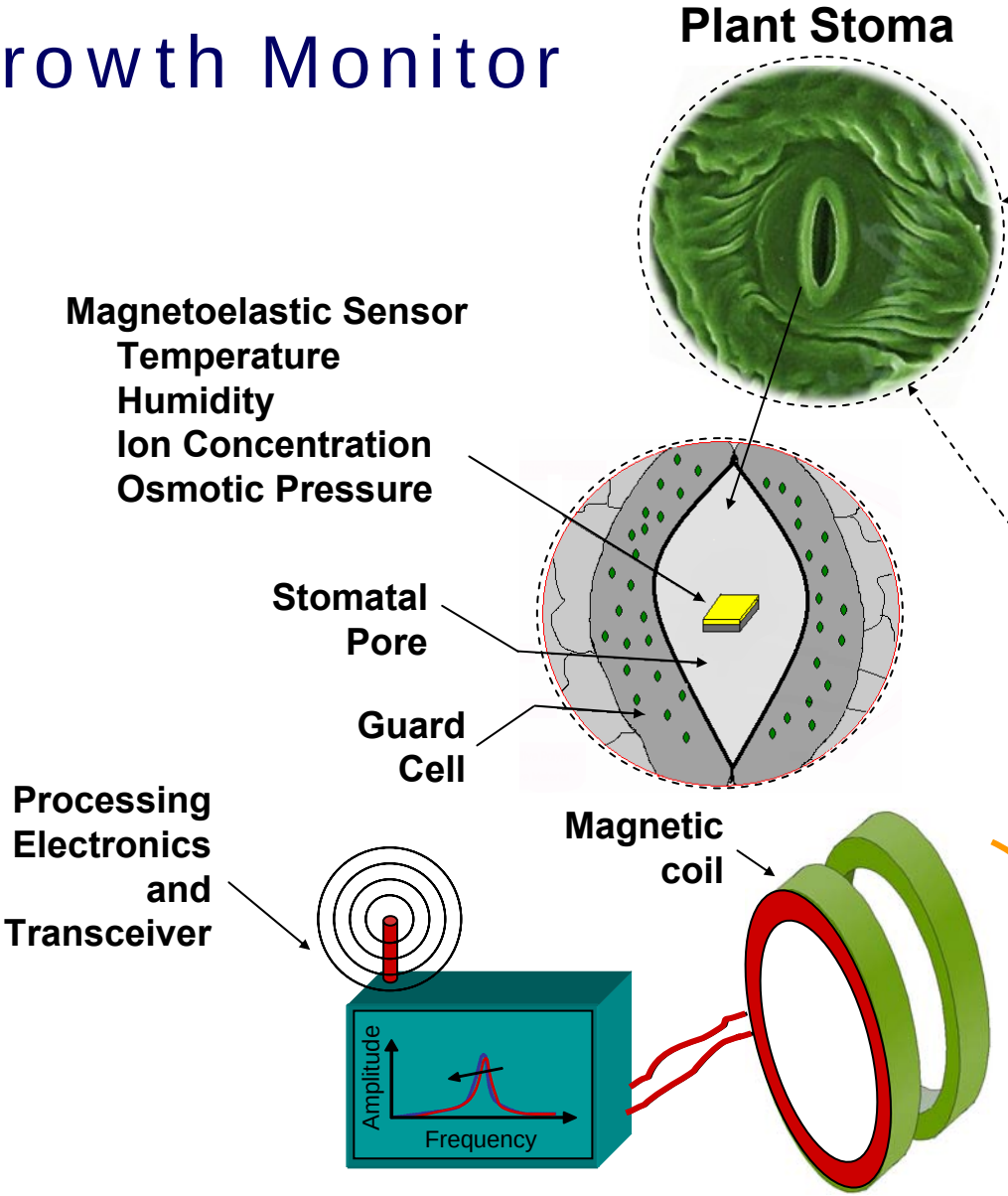
Magnetostrictive Particle Sensor



Measuring the Ripeness of Fruit via Ethylene Emission Monitoring

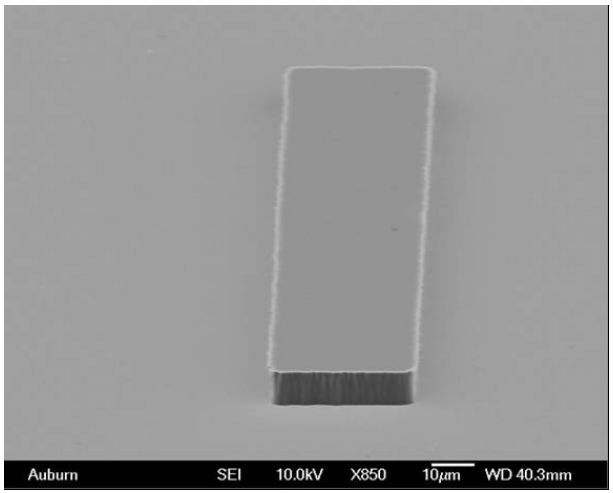


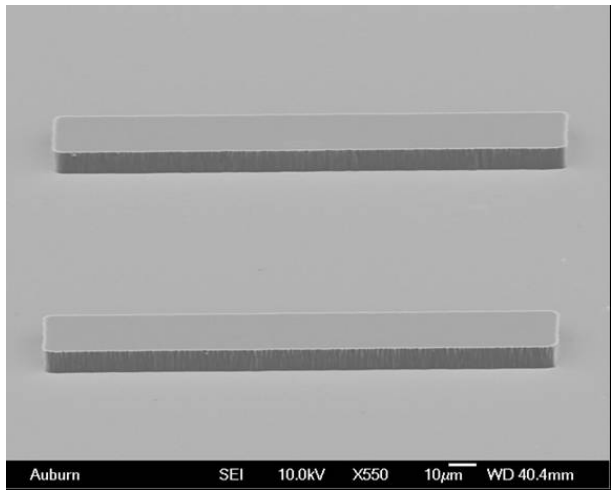
Internal Plant Growth Monitor

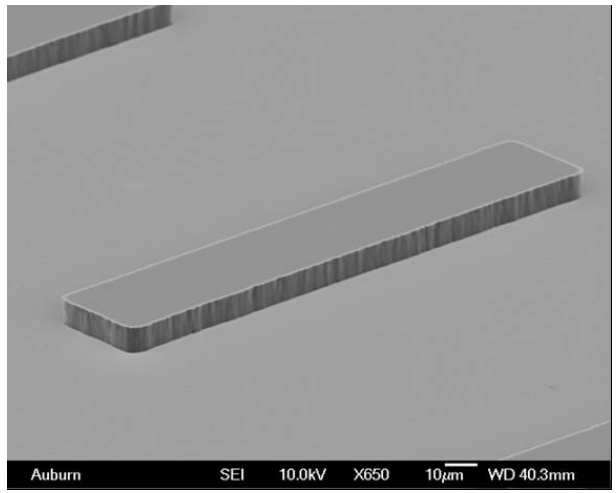


Photoresist Liftoff Process

SEM images of a 200 x 40 x 9.5 μm pattern:

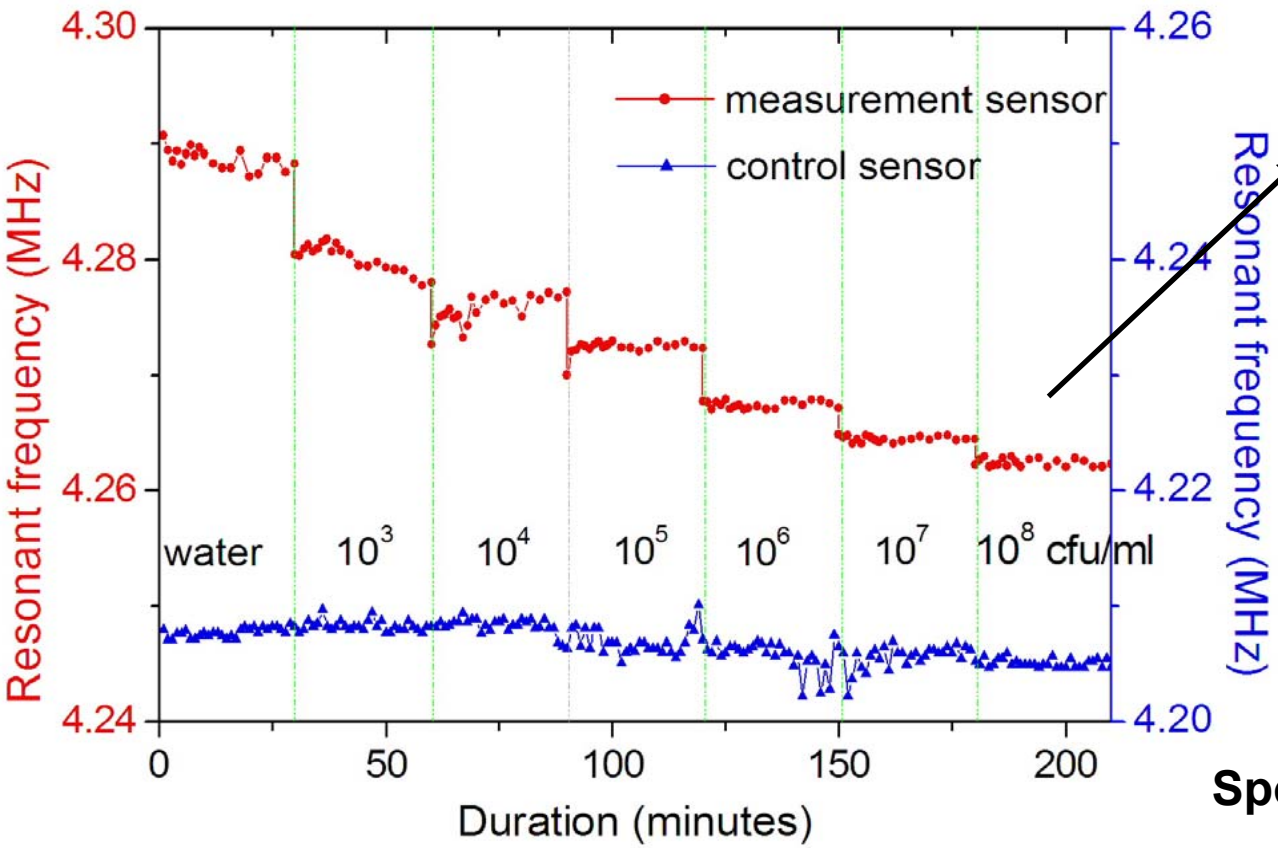




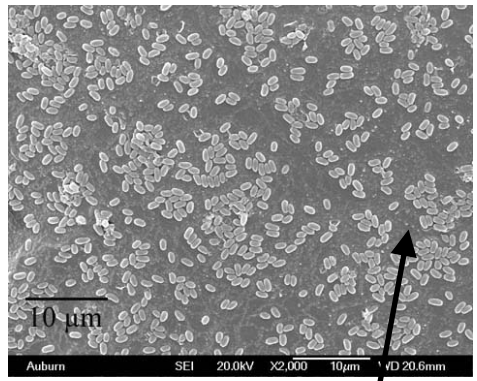


Note the vertical side-walls, a non-traditional lift-off structure.

Magnetostictive Particle Detection of Bacillus anthracis spores in water

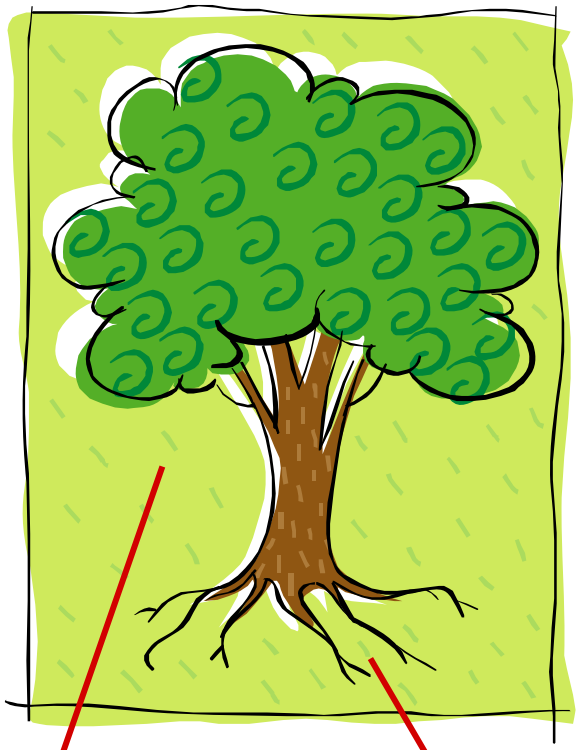


SEM of Sensor Surface



Spores Bind to Sensor

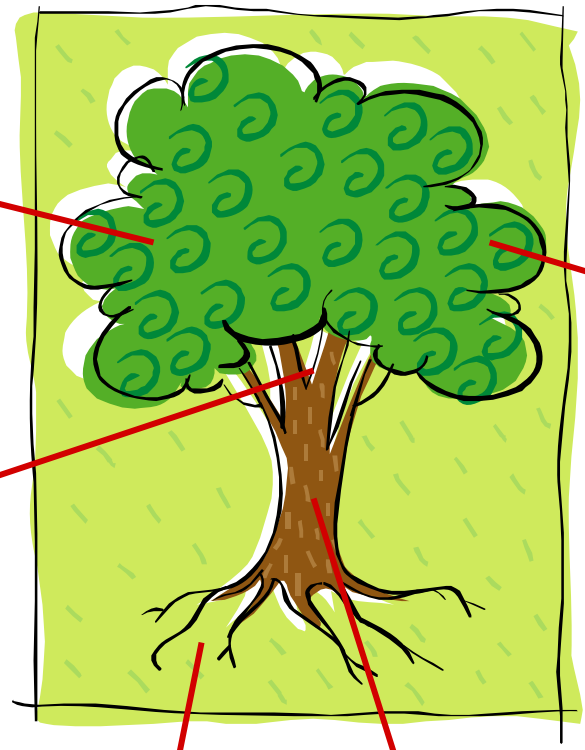
TODAY



Air temperature, humidity, and light intensity

Soil moisture, temperature, and pH

FUTURE



Photosynthesis efficiency

Carbon dioxide intake

Herbivore attack, phytoalexin, or protein inhibitor detection

Nutrient flow

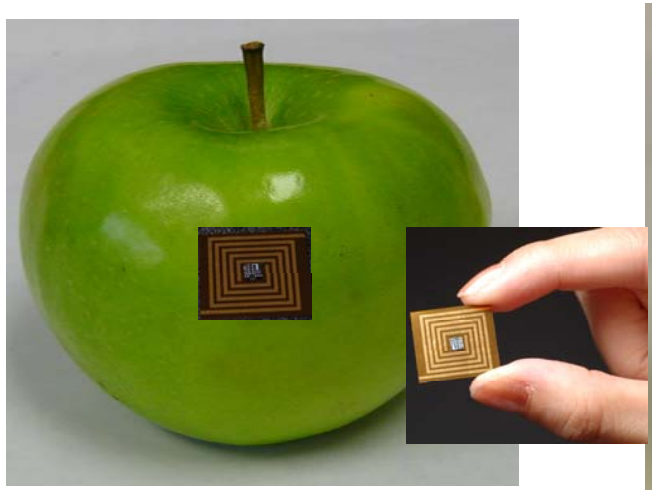
Osmotic pressure and mass transfer

TODAY

PAPER LABELS

TOMORROW

5 TO 10 YEARS

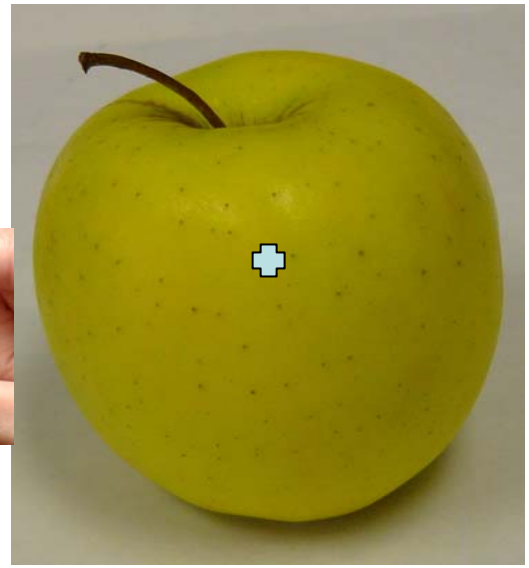


RFID TAGS

- **Temperature**
- **Ripeness**
- **Impact**
- **Cull ?**
- **Water Content**
- **Surface Bacteria, Pesticides**
- **Traceability**

FUTURE

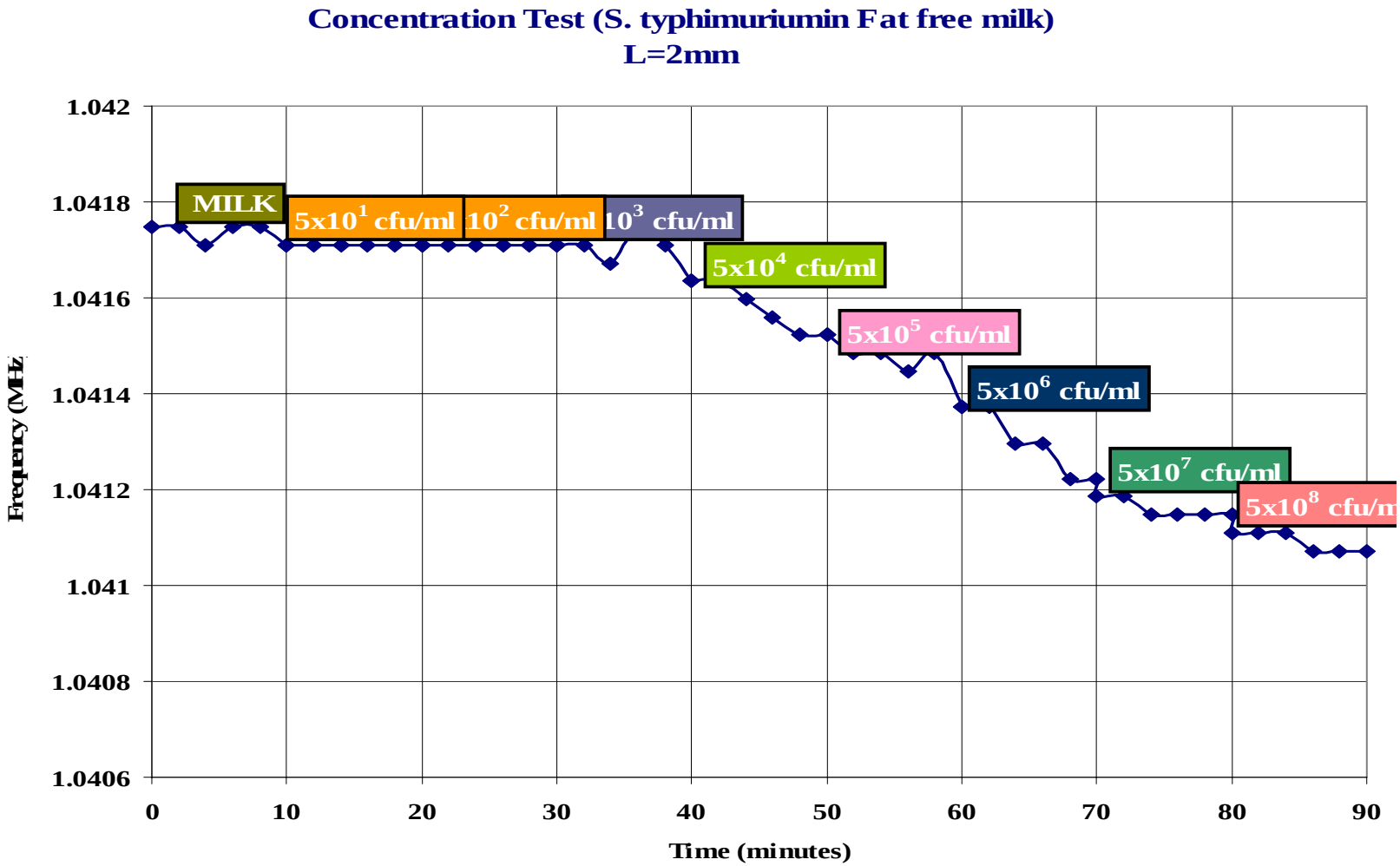
10 + YEARS



WIRELESS

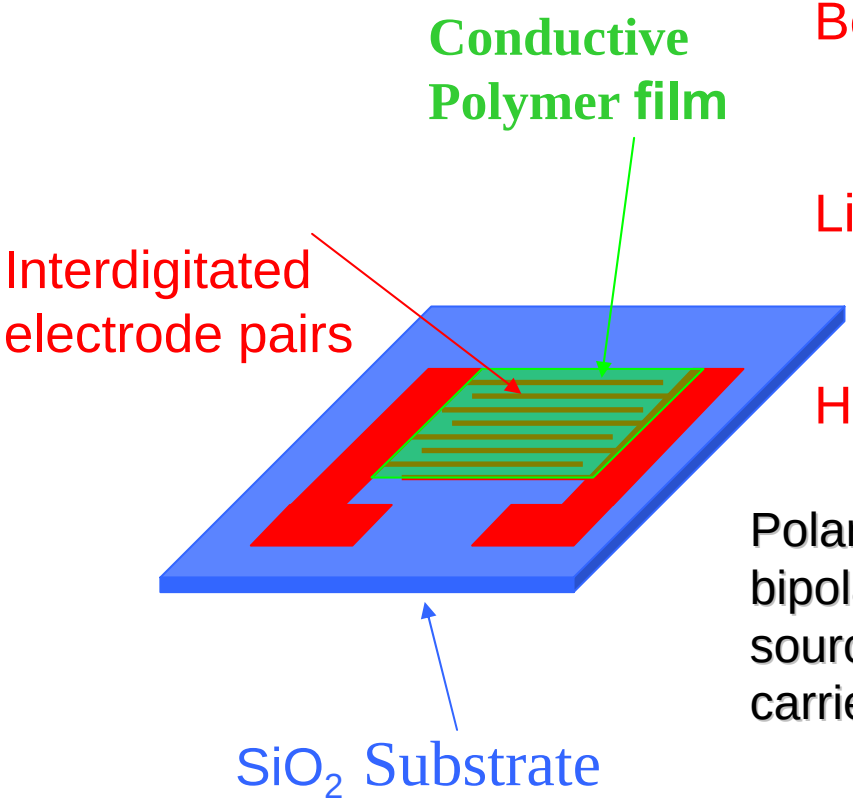
- **Sweetness**
- **Consistency**
- **Color**
- **Best Consumption Date**
- **Whole Product: Bacteria, Pesticides & Allergens, Phytosanitary**

Questions ?

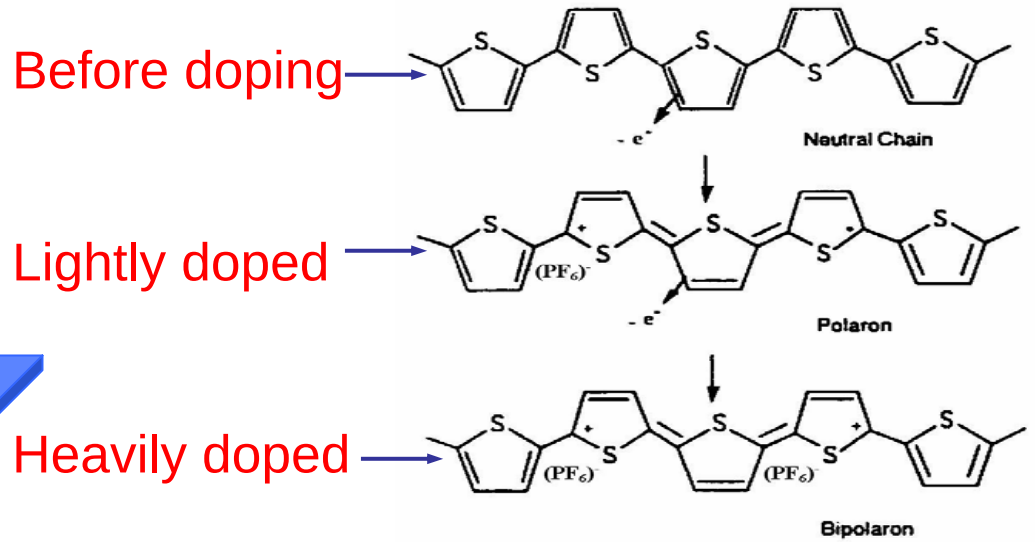


Magnetoelastic biosensor's response when exposed to different concentrations (5×10^1 through 5×10^8 cfu/ml) of *S. typhimurium* suspensions in fat free milk. Fat free milk with no bacteria was used as the reference. Data was recorded at two minute intervals. Each concentration of bacterial suspension was run for 10 minutes at a flow rate of 100 ml/min.

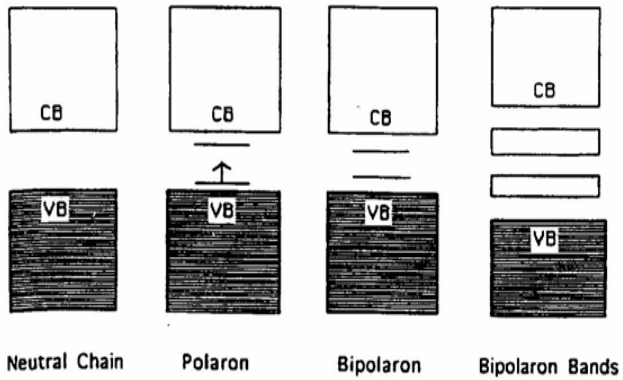
Sensing Mechanism

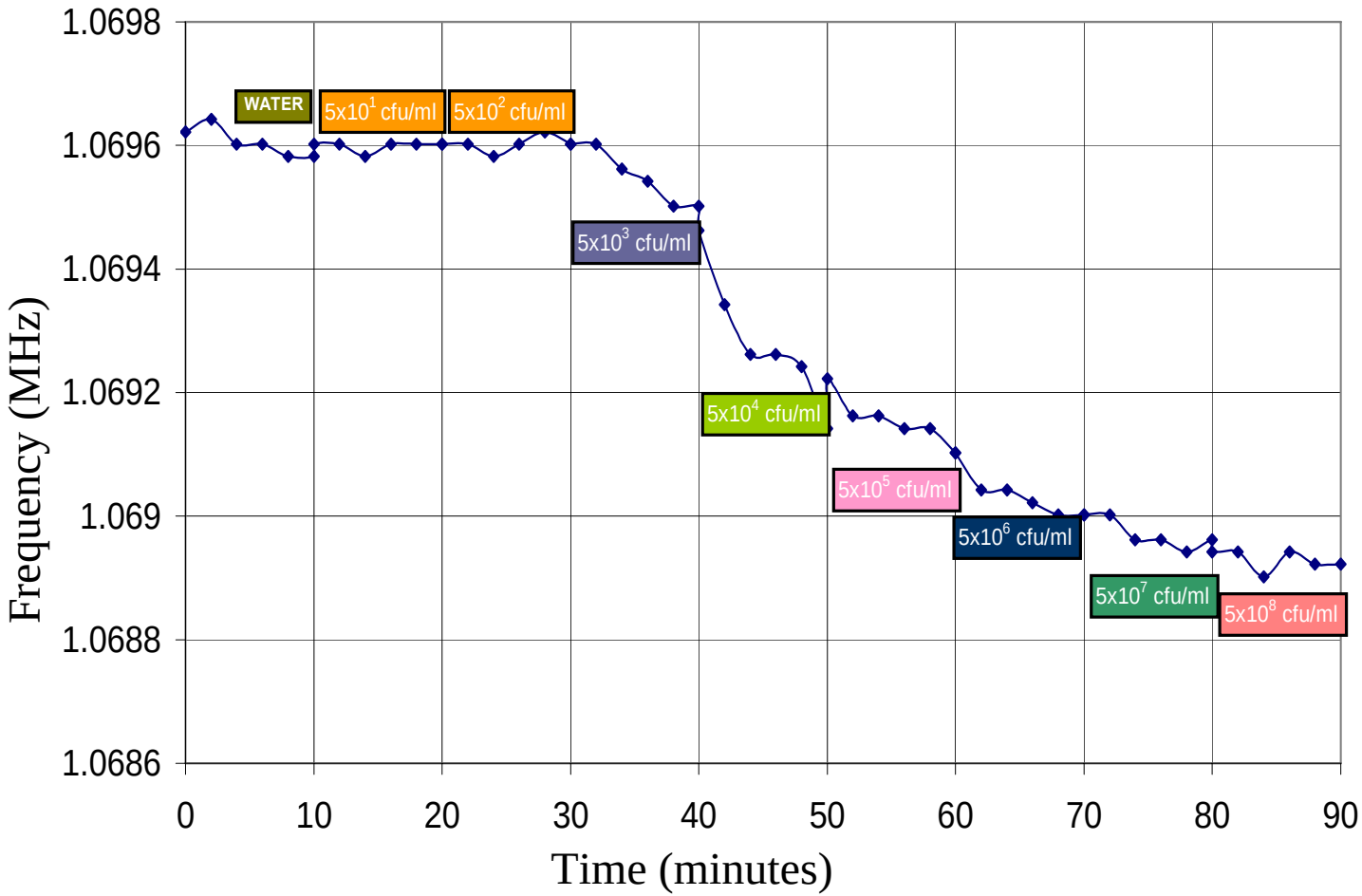


NOPF6 doped polymer structure



Polarons and bipolarons are the source of charge carriers





Magnetoelastic biosensor's response when exposed to different concentrations (5×10^1 through 5×10^8 cfu/ml) of *S. typhimurium* suspensions in water. Water with no bacteria was used as the reference. Data was recorded at two minute intervals. Each concentration of bacterial suspension was run for 10 minutes at a flow rate of 100 μl/min.