A fast, simple food safety check

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Magne electroelastic biosensors detect food-borne pathogens on-site, directly, and in real time. Preventing food-borne illnesses depends on quick detection of pathogenic micro-organisms. However, lengthy food supply chains provide many opportunities for contamination, and identifying contaminated food presents a challenge. Accurate, real-time, and on-site pathogen detection would improve food safety and reduce the sickness and even death caused by food-borne pathogens.

Colleagues and I have investigated freestanding magnetoelastic (ME) biosensors as label-free wireless devices for real-time pathogen detection. An ME resonator is coated with a surface containing an element that binds specifically with a target pathogen. The ME resonator is a rectangular amorphous ferromagnetic alloy that changes its dimensions in the presence of an external magnetic field by magnetostriction: in an alternating magnetic field, the resonators undergo a corresponding oscillating shape change that produces a mechanical vibration with a characteristic resonant frequency. When the target pathogen binds to the surface coating, it reduces the sensor’s resonant frequency, which can be monitored wirelessly. In this way the presence of the target pathogen is detected.

By acting through magnetic fields, the ME biosensors have the unique advantage of detecting pathogens without physical wire connections between the sensor and the pickup coil, enabling versatile in situ detection of pathogens. In addition, multiple ME biosensors can be easily monitored using a measurement magnetic field that covers a broad area, enabling simultaneous detection of extremely low concentrations of multiple pathogens in large-volume samples.

The ME biosensor sensitivity exponentially increases as its size decreases. By employing photolithography and physical vapor deposition, microscale ME resonators have been fabricated with precisely controlled dimensions and surface quality. Using 500 × 100 × 4μm ME biosensors, a detection limit of ~50 colony-forming units (cfu)/ml has been achieved in real time when detecting Salmonella, a major food-borne pathogen that has caused several infamous outbreaks of food poisoning in the US. Multiple ME biosensors have also successfully detected spores of Salmonella and Bacillus anthracis (which causes anthrax) simultaneously.

We have demonstrated direct detection of Salmonella on a tomato surface using ME biosensors coated with a genetically engineered ‘E2’ phage. We measured the ME sensor’s resonance frequency by placing the sensor inside a solenoid coil; detecting a change in sensor frequency required two separate measurements, before and after bacteria exposure. Since then, we have improved the technique by using a surface scanning coil. In this new method, a planar coil is placed just above the ME sensor and detects magnetic flux emitted from the vibrating ME sensor to measure the resonant frequency, permitting continuous, real-time measurement during bacteria exposure.

Figure 2 shows the real-time frequency changes of ME biosensors measured by the surface scanning coil when the sensors were placed on a tomato surface that was spiked with Salmonella at a concentration of 1.5 × 10^6 cfu/mm². Figure 2(a) and (b) represent the measurement results in 95 and 50% relative humidity environments, respectively. In Figure 2, the solid line shows the

Continued on next page
frequency changes of a measurement biosensor during bacteria exposure, while the dashed line shows the frequency changes of a control biosensor. The control sensor was identical to the measurement sensor but without the coating of the biomolecular recognition element. The difference in resonant frequency between the measurement and control sensors therefore indicates the presence of the target *Salmonella* cells.

In summary, ME biosensors provide an inexpensive, accurate, and easy way to detect contaminated food, identify critical hazard points, and track contamination sources, effectively securing our food supply chain. In future work, we will integrate the ME biosensors, planar coils, and microfluidic system to form a portable lab-on-a-chip, allowing high-throughput on-site pathogen detection.

![Figure 2. Real-time frequency changes of ME biosensors directly placed on Salmonella-spiked tomato surfaces at different levels of relative humidity (RH): (a) 95%RH and (b) 50%RH (solid curves show response of the measurement biosensor, while dashed curves show one sample of the control biosensor response).](image)

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References