Report for 2005AL39B: Detection of E. coli in Source Water Using a Novel Biosensor

Publications

- Articles in Refereed Scientific Journals:
  - Li, Suiqiong; Lisa Orona, Zhimin Li, Z. Y. Cheng, 2006, Biosensor Based on Magnetostrictive Microcantilevers as Sensor Platform, Virtual Journal of Nonascle Science and Technology Applied Physics Letters 88, 073507.
- Conference Proceedings:
  - Cheng, Z. Y., 2005, Applications of Smart Materials in the Development of High Performance Biosensors in Materials and Devices for Smart Systems, Materials Research Society, Boston, MA, Vol. 888, V10.6.1
  - Li, Suiqiong; Lisa Orona, Z. Y. Cheng, 2005, Electrosynthesis of Magnetostrictive Nanosensor Array in Nanoparticles and Nanostructures in Sensors and Catalysis, Materials Research Society, Boston, MA, Vol. 900E, 08.4.1

Report Follows

Final Project Report

Project Title: Development of a Cost Effective Methodology for in-field screening TEST of water quality

Sponsor: U. S. Geological Survey through the Alabama Water Resources Research Institute)

Duration: 03/01/2005 to 02/28/2006

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Statement of the problem and research objectives

Continuously monitoring the quality of various waters is highly needed for safe drinking water practice and smart agriculture. The biological quality of water, which represents the presence and concentration of microorganisms in the water, is an important part of the task. The types of microorganisms in water can be a great number. Therefore, EPA recommends *E. coli*, which comes from human and animal wastes and is the most common form of fecal coliform, as the best indicator of health quality standards and are monitoring accordingly. By observing *E. coli* bacteria, the increase or decrease of many pathogenic bacteria can be estimated. Additionally, the presence of *E.coli* in a body of water may indicate that more harmful bacteria, viruses, or other microorganisms have contaminated that body of water.

In Alabama, there are families using private wells as their primary water resource. Therefore, a device, which can be used by individuals without training for monitoring the quality of the water from the well in a real-time manner, is highly desirable. Alabama is rich in source water, such as Lake Martin and many rivers/creeks. The quality of source water is the key to ensure the quality of drinking water. Therefore, monitoring the quality of source water would be very critical. Additionally, the data from water quality monitoring is very critical to determine the source of pollution and would help local farmers use the land more efficient. Therefore, an inexpensive biosensor/technology that is suitable for field testing is urgently needed for monitoring quality of source water in a real-time manner.

Due to the importance of water quality and the complexity of the problem, the EPA has implemented many technologies for monitoring water quality. However, all the technologies recommended by EPA are laboratory-based. That is, the water samples have to be delivered to a laboratory from the sources. The current EPA recommended technologies require the water samples to be delivered to a laboratory within 6 hours on ice. More importantly, the analysis of the water samples requires trained personnel and includes a 24-hour incubation period, which makes the analysis a time consuming process. In order to test the water quality in a real-time manner, it is believed that biosensors would be a strong candidate. Many types of biosensors have been developed or are under development. However, there is yet no biosensor suitable for in-field screening of water quality.

This project was designed to develop a new device/methodology of monitoring water quality by detecting the concentration of *E. coli* in the water in a real-time manner. The device to be developed is based on the magnetostrictive particle (MSP) technology recently developed by the Principal Investigator. The device is ideal for in-field screening.

Research Methodology

The methodology is based on the newly developed MSP (magnetostrictive particle) technology. The MSP technology is an acoustic wave device. The MSP is a wireless sensor platform with a sensitivity much better (100 times) than the state-of-the-art microcantilevers. More importantly, the MSPs work well in liquid including water. The MSP is coated with antibodies against *E. coli* on its surface. The antibody as a bio-probe captures the target bacteria, *E. coli*. The capture of target species onto the surface of MSP results in a change in the resonance frequency of the MSP. Therefore, by measuring the change in resonance frequency of the MSP, the number of bacterium cells captured on the MSP surface can be calculated. The resonance frequency of the MSP is continuously monitored wirelessly using magnetic signals. When the target species are bonded on to the antibody, which was immobilized on the MSP surface, the mass load of the MSP will change, which results in a change in resonance frequency. Therefore, the capture of target species by the MSP can be determined in a real-time manner. The target species captured by the MSP present the concentration of the bacteria in the water sample. More importantly, many MSP sensors can be employed at the same time and the capture of target species by one of many MSP sensors can be determined, which significantly enhance the apparent sensitivity of the MSP technology. Additionally, the MSP sensors in the water sample can be stirred using a magnetic field, which brings the sensor to target and therefore increases the possibility for the MPSs to capture the target species in the water sample. The performance of the MSP sensors was tested in air and water. The high performance of the MSP sensors was demonstrated in these experiments.

The objectives of the project are: 1) Immobilizing the antibody onto the surface of the MSPs and fabricating the MSP biosensor for detecting the *E. coli* bacteria in water. MSPs in lengths from 1000 to 50 μm and in thickness from 1 to 10 μm will be fabricated. The antibody against *E. coli*, which is commercially available, will be immobilized onto the surface of MSP as the receptor. Different techniques, such as Langmuir-Blodgett (L-B) technique and the direction physical adsorption, will be employed to immobilize the antibody. The optimum process for immobilizing the antibody onto the surface of the MSPs will be determined; 2) Building a prototype device based on the MSP-technology. All the sensors will be characterized under controlled laboratory conditions; 3) Determine the performance of the MSP sensor; 4) Improve the integating system to evaluate the feasibility of developing a handheld device and the methodology for in-field testing of water quality based on the MSP technology; 5) training students, and 6) submitting proposals for additional funding.

Research findings and their significance

The magnetostrictive thin film (amorphous FeB alloy) in a thickness from 10 μm down to 1μm was prepared using sputtering and electrochemical deposition. It was experimentally found that the FeB thin film exhibits a great magnetostrictive effect required for developing high performance biosensor based MSP technology. The MSPs in lengths from more than 1000 μm down to 50 μm were fabricated from the FeB thin film. The antibody against *E. coli* has been successfully immobilized onto the surface of the magnetostrictive thin film using the direction physical adsorption. All these achievements form a solid foundation for developing MSP biosensors for detecting *E. coli* in water samples. The specifications and performance of MSP sensors in lengths from 500 μm to 2000 μm have been determined. The results indicate that the MSP sensors have a greater performance than other sensors. The integation system was modified. A new system was built. The results demonstrated the feasibility to fabricate an integation system for the MSP sensors in a price range of a couple hundred dollars. All these results are consistent with our previous estimation. All these indicate that using the MSP technology as a cost-effective device can be developed for monitoring water quality in a real-time manner.

Continuing support is needed to combine all these achievements together to develop a real device for monitoring water quality.