Abstract

Ruoxi Wu. Ph. D., Purdue University, May 2014. Real-Time Monitoring of Potable Water Characteristics in a Water Distribution System. Major Professors: Rao S. Govindaraju and M. Katherine Banks.

A self-powered mobile sensor is designed and fabricated for water quality monitoring in a potable water distribution system. In contrast to traditional stationary water sensors, a mobile sensor moves with the water flow, which allows it to locate a contamination in water distribution pipes and provide a faster response. The wireless mobile sensor was fabricated and tested in water distribution pipes for monitoring pH, $Ca^{2+,}$ Mg^{2+}, HCO_3^-/CO_3^{2-}, NH_4^+, Cl^-, and residual chlorine based on micro electrochemical sensor. Moreover, an energy-harvesting system is designed for the mobile sensor.

The spherical mobile sensor consists of a multi-analyte-biochip (MAB), microfluidics, electronics, and an energy harvesting system. The MAB measures key environmental analytes. The microfluidics has a MP6 micropump with a pumping rate of 6 ml/min, with microtubing that takes samples from the water environment to the sensor. The electronics consists of DAQ and a wireless transmitter that communicates to the stationary signal receiver located outside the pipe. The energy-harvesting system allows the mobile sensor to sustain function without power supply.

The multi-analyte biochip was designed and fabricated via standard microfabrication technology. Each MAB has nine solid-state working electrodes (WEs) equidistance from their paired Ag/AgCl reference electrodes (REs), enabling multiplex measurements of analytes. The working electrodes were functionalized with the conductive polymer conjugate poly(3,4-ethylene dioxythiophene) (PEDOT) and an ion-selective membrane for the analyte of interest. The MAB is housed in a microfluidic flow-cell chamber wirebonded to the PCB that connects to the DAQ unit and wireless transmitter.

Wireless System The mobile sensor is designed to be deployed at a water treatment plant and retrieved at a hydrant. The sensor network has a base station that is connected to multiple stationary receivers. Each stationary receiver collects wireless data from multiple mobile sensors.

The mobile sensor is designed to harvest energy from device rotation and impact with the pipe. The energy harvest system consists of multi-pole, air-core permanent magnet, spring, coil, and diode rectifier packaged within a rigid body device of arbitrary geometry. Simulated energy output for a sphere of radius 5.08 cm is 78.74 mJ for each impact with the pipe.

The correlation between concentration and electromotive force for analytes of interest follows the Nernstian equation. The ion concentration range of potable water is within the calibrated MAB detection range. A real-time water-quality monitoring test is designed to verify the functionality of the mobile sensor. The wireless signal received at the base station shows a voltage change that represents a change in pH of the test solution.