Development of Novel Portable Explosive Detection Systems

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In this paper we present the recent research and developmental results on a novel wireless explosive detection system. An emerging sensing technology in micro/nanoelectromechanical system (MEMS/NEMS) and wireless information and communications technologies have been combined in developing a novel explosive detection device that can simultaneously monitor several explosive compounds in a real time.

The explosive detection device is based on an array of microbridges fabricated on a single chip that includes mechanical and electronic components for smart actuation and sensing of explosives. The design provides portable, transportable and movable monitoring device. Explosive detector characteristics include real-time response, miniature size, low power and cost, and high mobility and reliability.

A finite element simulation has been used for optimization of piezoresistive silicon covered SiO₂ microbridges. Microbridges have been fabricated with a commercially available ROI wafer. The dimensions of the designed microbridge are 400 µm in length, 50 µm in width, and 1 µm in thickness. The thickness of the top boron Si and the following SiO₂ insulator were 2 µm and 1µm, respectively. The dimensions of the silicon piezoresistor on the bridge were 400 µm in length, 10 µm in width and 2 µm in thickness. The microbridge resistance variations due to the surface stress changes were systematically investigated by varying microbridge geometries and the boron doping concentrations in silicon. Simulation results have shown that the resistance change of the microbridge is directly related to the actuation of the microbridge and that better sensitivity can be obtained with thinner and narrower silicon piezoresistor and the SiO₂ microbridge. Based on these simulations, the piezoresistive microbridges have been fabricated. Fabricated microbridges were found to be more stable than microcantilevers in terms of undesired oscillations.

An electronic module for the explosive microbridge-based sensor actuation and sensing interface has been developed. The presence of the explosive compounds is detected as a variation of the voltage due to microbridge oscillations. The microbridge oscillations cause the oscillatory change in the microbridge resistance and are detected by the interface circuit and the microcontroller. Based on experimental results and fabrication data we have concluded that the nominal microbridge resistance is 1 MΩ. Previous experiments in explosive detection have indicated that the required current needed to heat the microbridge-based sensor is around 20 µA. This provides a voltage drop of 20 V across the microbridge, creating an output reading source. Sensor interface consists of constant current source that is controlled by the microcontroller. The microcontroller initiates microbridge actuation, followed by the sensor readings that are read by the microcontroller A/D converter.

Once sampled data have been collected by the microcontroller, a software algorithm processes the data and decides if there are explosive molecules on the microbridge or not. The algorithm is implemented in C for an easy integration with TinyOS-based wireless sensor nodes. In order to reduce the false alarm occurrences NO₂ sensor will be added and data base of false alarm signatures will be created at the system base station. Upon microbridge oscillation has been detected, the microcontroller will check the reading of NO₂ sensor and, if detected, alert the base station of possible explosive detection. The sensor node will also send the full signature data to the base station. The base station will correlate newly received microbridge oscillation data with existing data base vectors and decide about final user alert.

Future work includes an integration of microbridge-based sensor array and electronics module into a single MEMS device.