Title: Enabling Crowd Sourced Environmental Monitoring  
Keywords: carbon monoxide, gas sensor, MEMS, nanoparticles

Introduction: What if everyone in Los Angeles, Mexico City, and Beijing were carrying around a multifunctional sensor that could communicate wirelessly to the cloud? Now imagine that this sensor can measure temperature, humidity, and carbon monoxide (CO) concentration. The collective knowledge of these sensors could map in real time where the smog levels rise to an unhealthy level and provide a first alert for environmental and medical responders. Many people in developed and developing countries are actually already carrying around a basic multifunctional sensor – their cell phone. Advanced research in MEMS sensor fusion will soon enable smart phone users to download a crowd sourcing application that makes them part of a mobile air quality monitoring network and helps protect the community’s health and safety.

I am currently working on sensor fusion in a research lab and developing an inexpensive self-powered multifunctional sensing node. As seen in Figure 1, this node includes an energy harvester, a multifunctional MEMS sensor, and a transceiver [1]. The 4mm² MEMS sensor can measure various properties including temperature, humidity, pressure, acceleration, and wind velocity [2]. I will contribute to the field by developing a micro-chemical gas sensor by applying elements of mechanics, chemistry, materials science, data analysis, and power management.

Objective: I aim to push the limits of sensor fusion infrastructure by addressing chemical sensors, which are currently underdeveloped inputs to the sensing system. Using the prototype platform in the lab, I will build from the initial work on multifunctional sensors by establishing a detailed procedure for manufacturing micro-chemical sensors and developing a chemical sensor that is sensitive to both carbon monoxide and hydrogen sulfide for use in a multifunctional sensor.

Background: Micro-chemical sensors consist of nanoparticles deposited onto comb fingers that sit on top of a micro-heater. Figure 2 shows tin oxide nanoparticles I deposited onto the sensor for one of my preliminary tests. One type of nanoparticle senses a respective gas. For example, in the presence of CO, the resistance of tin oxide nanoparticles will drop and current increases between the comb fingers [3]. In my preliminary research, I observed that the deposition process significantly changed the behavior of the nanoparticles. Existing literature rarely details this step, however, and an established procedure does not exist.

Aim 1: The first aim of my research is to optimize the procedure of depositing nanoparticles onto the comb fingers to improve sensitivity. Evenly distributed gas
sensing nanoparticles can detect CO at toxic levels. Variables that are considered when depositing the nanoparticles include the type of pipette, the pipette orientation, the solution volume, and whether or not to sinter the nanoparticles. Isolating the effects of the procedure variables will determine how to deposit the nanoparticles to make the most effective chemical sensor. Based on my experience depositing nanoparticle solutions, I hypothesize that the optimal volume of the solution to deposit will be less than 5nL, and that the optimal concentration will be higher than 10mg/mL [4]. I also expect that sintering will not have an immediate effect on sensitivity, but will improve the durability of the sensor.

**Aim 2:** The second aim of my research is to develop a deposition method for high volume production. Inkjet printing has been used to deposit silver nanoparticles onto polyethylene terephthalate for a capacitive humidity sensor and current 10nL inkjet printers drop cartridges could print on the scale required for the micro-chemical sensor [5]. When producing batches of multifunctional sensors, the nanoparticles could be deposited onto the chemical sensor comb fingers before the chips are cut from the wafer.

**Aim 3:** The third aim of my research is to integrate several gas sensing nanoparticles so one micro-chemical sensor can identify multiple gases. The ability to sense different gases with one sensor would increase the functionality of an integrated sensor without increasing size. At the National Institute of Science and Technology, tin oxide and tungsten oxide nanoparticles have been combined onto one micro-chemical sensor by using sacrificial hollow microspheres [4]. I will further explore and develop interconnected microspheres because this method may create the most effective nanoparticle solution for deposition onto a micro-chemical sensor.

An advantage of the multifunctional sensing node is that it allows for compensated measurements and mitigates the effects of false positives. Testing the micro-chemical sensor involves first confirming its sensitivity to carbon monoxide then mapping its cross sensitivity to temperature and humidity as part of the multifunctional sensing node. I have helped perform basic tests using the gas vacuum tube, nitrogen gas, and carbon monoxide gas. In the future, I will test a commercial carbon monoxide sensor at the same time as developing this sensor to compare their sensitivity and range.

The **intellectual merit** in this work lies in developing the procedure for creating a micro-chemical sensor and in creating a micro-chemical sensor as part of a multifunctional MEMS sensor. This work will **potentially transform** the oncoming wave of multifunctional sensors by including toxic chemical sensing in their capabilities. Multifunctional sensors with micro-chemical sensors will create a **broader impact** on the health and safety of the population as well as provide an educational tool. A multifunctional sensor allows students to investigate the world around them with hands-on projects and will enable a crowd source environmental monitoring network.


I, Bridget Eileen Hill, attest to the originality of this research proposal.