Grant: AFC518-02

Title: Miniaturized and Real Time Gas Sensors for Mine Safety and Health

Organization: Oakland University

Principal Investigator: Xiangqun Zeng

Topic: Environmental and Atmospheric Monitoring Devices

Concept Summary:

Technology Development Challenges and Approaches: Despite improvements in safety regulations, workers in mines continue to experience dangers from hazardous gases, as evident from the numerous reports of injuries and health related issues linked to gas explosions and toxic gas emissions. One of the solutions to address these problems is the use of personal gas sensors in mines. Although many handheld gas sensors have been developed, none of them meets the challenging set of performance and utility requirements that would enable the pervasive use of personal, continuous-use, multi-gas monitors in different mine environments.

Objectives and Research Approach: Real-time and continuous-use gas sensors are needed for monitoring gaseous analytes (e.g. explosive gases) to reflect the dynamic gas environment for the safety and health of mineworkers. Compared to other chemical sensor options (e.g. optical or solid state based sensors), electrochemical (EC) gas sensors possess an impressive capacity to achieve the analytical requirements of continuous monitoring of analytes within a small footprint, are constructed with low-cost materials and fabrication techniques, and are controlled by compact low-power microelectronic circuits. However, EC sensors require the use of aqueous (i.e. water) or non-aqueous (i.e. organic solvents) electrolytes which are prone to solvent exhaustion and have a limited applicable potential window. In the past years, we have pioneered an ionic liquid (IL) based EC gas sensor technology (IL-EG) that has performance specifications meeting the gas monitoring requirements for mine safety heretofore unavailable in existing gas sensors. ILs are non-volatile and conductive which allows continuous sampling with near–proximity measurements, and their non-volatile and non-flammable characteristics enable IL-EG sensor to be used in more extreme operating conditions such as explosive hazardous environments. Our early work also allows us to establish the link of the analytical performance of the IL-EG sensor and the construction/design and materials from which the sensor is made, as well as the many factors impacting the optimal sensor operation and performance. Thus, in this concept proposal, we propose to establish a proof-of-concept of the IL-EG sensor technology for its use, adoption, and adaptation into mine practice with two objectives: *1. Sensor chip miniaturization for an IL-EG sensor prototype; 2. Miniaturized IL-EG sensor characterization and validation for accurate and reliable measurements in regard to confounding factors such as temperature and humidity variations that exist in mining environments.* Our Phase I concept proposal will focus on methane, hydrogen and oxygen as our gaseous analytes due to their significant relevance to mine safety. The proposed IL-EG sensor is expected to operate in an explosive environment and the real time sensing with a low cost and low power electrochemical transducer will allow them to be distributed in mines to provide area-wide sensing instead of point measurements common with current technologies.

Expected Outcome: A miniaturized IL- EG sensor for detection of methane, hydrogen and oxygen with the required accuracy, repeatability, and stability of hazardous gas detection in mining environments will be developed and validated for its use, adoption, and adaptation into mine practice.

Anticipated Endpoint: With additional phase II funding, a miniaturized, low-cost, low-power, highly reliable, multi-analyte gas sensor system is expected to be developed to provide continuous real-time measurements of mine gases with the cost, power consumption, size and ease of use for mining operations. In Phase II, an IL-EG miniaturized sensor system will be developed that includes the detection of a large set of mine gases (methane, hydrogen, sulfur dioxide, nitrogen dioxide, carbon monoxide, oxygen) with additional multimodal sensing modalities (e.g. piezoelectric sensing module). The IL-EG sensor system will be further optimized to enhance sensor reliability and extend sensor life time in mine environments. Due to advances in portable electronics, microsensor technologies, and wireless communications, it is expected the final IL-EG sensor system can be integrated with the ad hoc networked communication systems to simultaneously address monitoring and communication needs.