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Sandia National Laboratories

Chemiresistors

Chemical microsensor for chemical warfare agent and toxic industrial chemical detection in air, soil, and water monitoring applications

What is the technology?

The chemiresistor is a small, simple, sensitive, rugged microsensor with low power requirements capable of detecting chemical vapors in air, soil, or water. As such, it is ideal for incorporation in a badge-type device to protect first responders from chemical exposure, or for serving as an environmental monitor for contamination (e.g., municipal water supplies). Chemical detection with the chemiresistor is possible through thin electrically-conductive polymer films that swell in the presence of volatile organic chemicals in the vapor phase; chemical concentration is indicated by the degree of swelling as measured through a change in electrical resistance across the film. Because the swelling of the polymer is reversible, the chemiresistor resets when the chemical disappears from the environment. Therefore, it can be used repeatedly without component replacement. An array of these miniature, low power devices has been used to detect multiple chemical contaminants. The chemiresistor has no moving parts and only requires simple DC circuitry to read electrical resistance.

What are the target applications?

Because of its small size and low power consumption, the chemiresistor's principal impact will be in a miniature, unobtrusive chemical sensing badge that can be worn by first responders. Other potential applications include facilities protection and contamination assessment.

Current status of the technology

Several chemiresistor prototype systems have been developed to address specific applications. The following illustrates the versatility of the technology:

- ***Groundwater Monitoring Sensor System***—A chemiresistor array has been packaged for placement in groundwater monitoring wells or other sites of environmental interest, as shown in Figure 1. The probe is fitted with a

Figure 1. Four-polymer chemiresistor array and temperature control system in stainless steel geologic probe with GORE-TEX® membrane for monitoring chemical concentrations in groundwater and/or soil.

GORE-TEX® membrane to allow chemical vapors through to the sensor while protecting sensitive electronics and wiring from contact with dirt, water, or other liquids. Chemiresistor probes have been placed in environmental monitoring wells for field-testing at Edwards Air Force Base, the Nevada Test Site, and the Chemical Waste Landfill at Sandia National Laboratories.

- ***Integrated Chemiresistor and Monitoring Electronics***—Illustrating the capabilities of microfabrication, the chemiresistor has been incorporated in a single die with all necessary circuitry to perform sensor resistance measurements. A four-element chemiresistor array with integrated electronics can be built in a space of approximately one square centimeter for applications where small size is the principal design consideration.
- ***Chemiresistor Microrobot***—Demonstrating the advantage of the integrated chemiresistor, this miniature device has been placed on a microrobot chassis for sensing of chemicals without the need for human exposure, as shown in Figure 2. Used with a "swarm" of microrobots, the chemiresistors can be used as a mobile distributed sensor system.
- ***First-Responder Badge Schematic***—A circuit diagram/device schematic has been developed for the first-responder chemical warning badge. This unit will be small and light weight with rapid, sensitive response and will alert emergency response personnel who could potentially be exposed to CW agents or TICs. A conceptual image of the first-responder badge is shown in Figure 3.

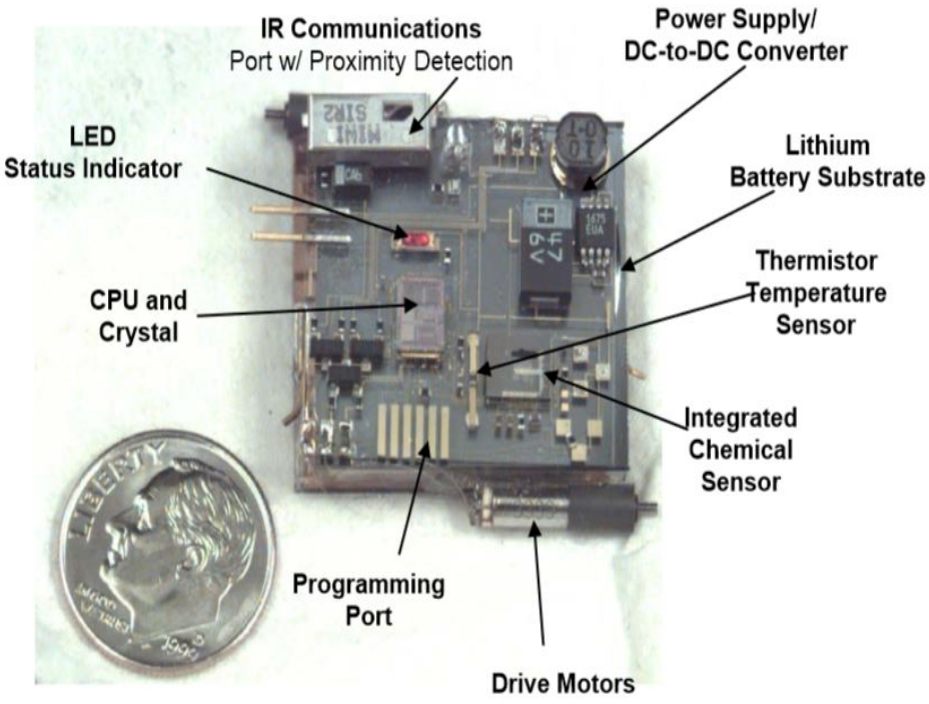

Figure 2. One-fourth of an integrated chemiresistor array (one polymer film and read-out circuitry) placed on a microrobot.

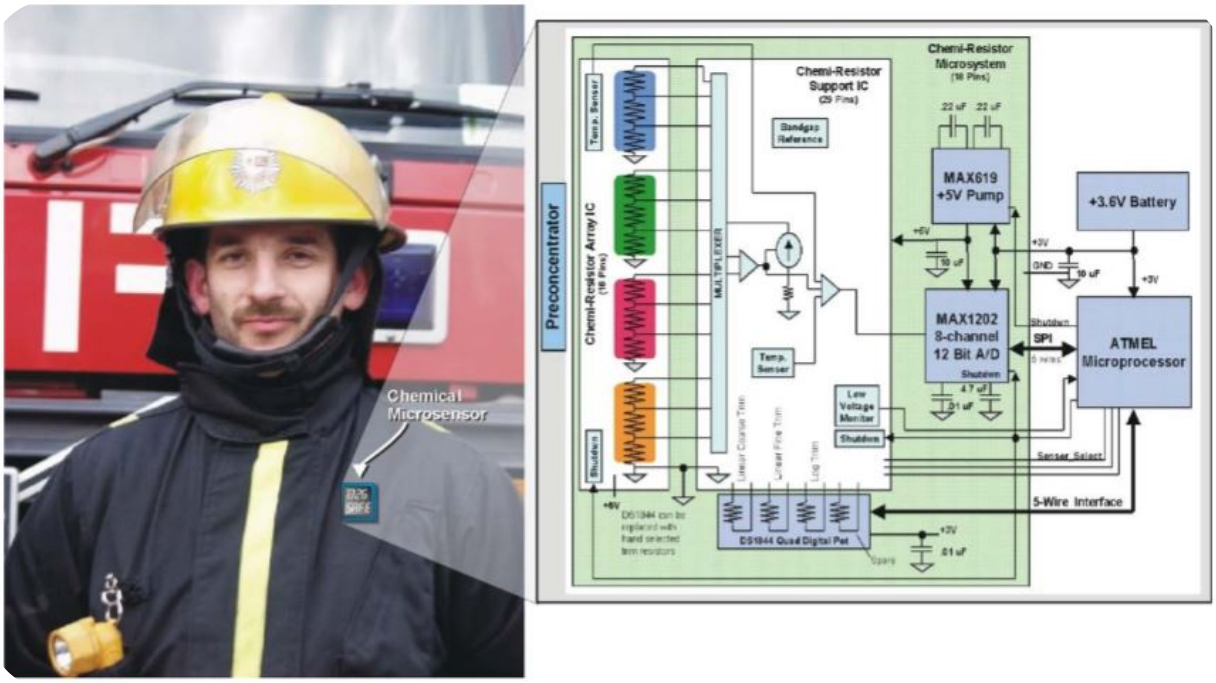

Figure 3. Conceptual picture and diagram of a chemiresistor as a first-responder badge for CW agent or TIC detection.

A general rule of thumb is that the chemiresistor can detect as low as 1/1000th of the saturated vapor pressure of a chemical of interest. Detection limits can then be improved up to 100 times through the combination of a preconcentrator with the chemiresistor.

Future Development

Near Term (1 year)

- Demonstration and testing of prototype first responder chemical badge.
- Chemiresistor/preconcentrator integration.

Mid Term (2-3 years)

- Development of nanomaterials for improved chemiresistor sensitivity, selectivity, and speed.

Long Term (3-5 years)

- Identify commercial partner for production of badge, and transfer technology to partner.

For additional information or questions, please email us at MGA@sandia.gov

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