Surface Acoustic Wave (SAW) Sensing

[Technology for the Detection of Nerve and Blister Agents]

Surface Acoustic Wave Sensing Technology

Introduction

Surface Acoustic Wave (SAW) sensors demonstrate superior selectivity for the detection of nerve and blister agents. Due to their solid state design and fabrication, SAW chemical sensors are extremely reliable. This paper describes the technology behind SAW and how this technology can be used for detection of chemical warfare agents.

SAW Technology

SAW sensors are piezoelectric crystals that detect the mass of chemical vapors absorbed into chemically selective coatings on the sensor surface. This absorption causes a change in the resonant frequency of the sensor. The internal microcomputer measures these changes and uses them to determine the presence and concentration of chemical agents. The SAW sensor coatings have unique physical properties which allow a reversible adsorption of chemical vapors.

The polymer films are normally chosen so that each will have a different chemical affinity for a variety of organic chemical classes such as hydrocarbon, alcohol, ketone, oxygenated, chlorinated, and nitrogenated. The selectivity of a polymer coating to a specific chemical vapor is determined by the type of molecular interaction between them. If the polymer films are properly chosen, then each chemical vapor of interest will have a unique overall effect on the set of devices. The SAW sensor coatings have unique physical properties which allow a reversible adsorption of chemical vapors. Therefore, the sensor will recover from exposure to the gas of interest.

To make a SAW instrument which is sensitive to nerve or blister agents, an array of SAW devices is used with each device having a different polymer film. Each film is chosen to have chemical absorption characteristics different from the others. Therefore, a SAW instrument designed for detection of nerve agents will have reduced cross-sensitivity to other compounds in the background stream. The array is housed within a package that has a pathway for vapors to enter the array, pass over all the SAW devices and then exit the device. The sensitivity of the system can be enhanced for low vapor concentrations by using a chemical concentrator before the array. (See Figure 1)

In operation, the concentrator adsorbs the test vapors for a period of time and is then heated to release the vapors over a much shorter time span, thereby, increasing the effective concentration of the vapor at the array.

An individual array can detect for the presence of either nerve or blister agent based upon their chemical class. The SAW instrument can then indicate whether or not nerve or blister agent is present, however, it will not identify specifically which nerve or blister agent has been detected.

Nerve and Blister Agents

Chemical Warfare Agents are typically divided into four categories. (See Table 1) Nerve agent is commonly abbreviated as a "G" agent (refers to "German" for the country discovering the compounds). There are four commonly known types of nerve agents; GA, GB, GD and GF. Their names are as follows: GA-Tabun, GB-Sarin, and GD-Soman and GF which does not have a common name. All nerve compounds belong to the chemical class of organo-phosphorus compounds. Nerve agents acquired this designation because they attack the nervous system affecting the transmission of nerve impulses. In general these substances can be easily dispersed and are highly toxic.

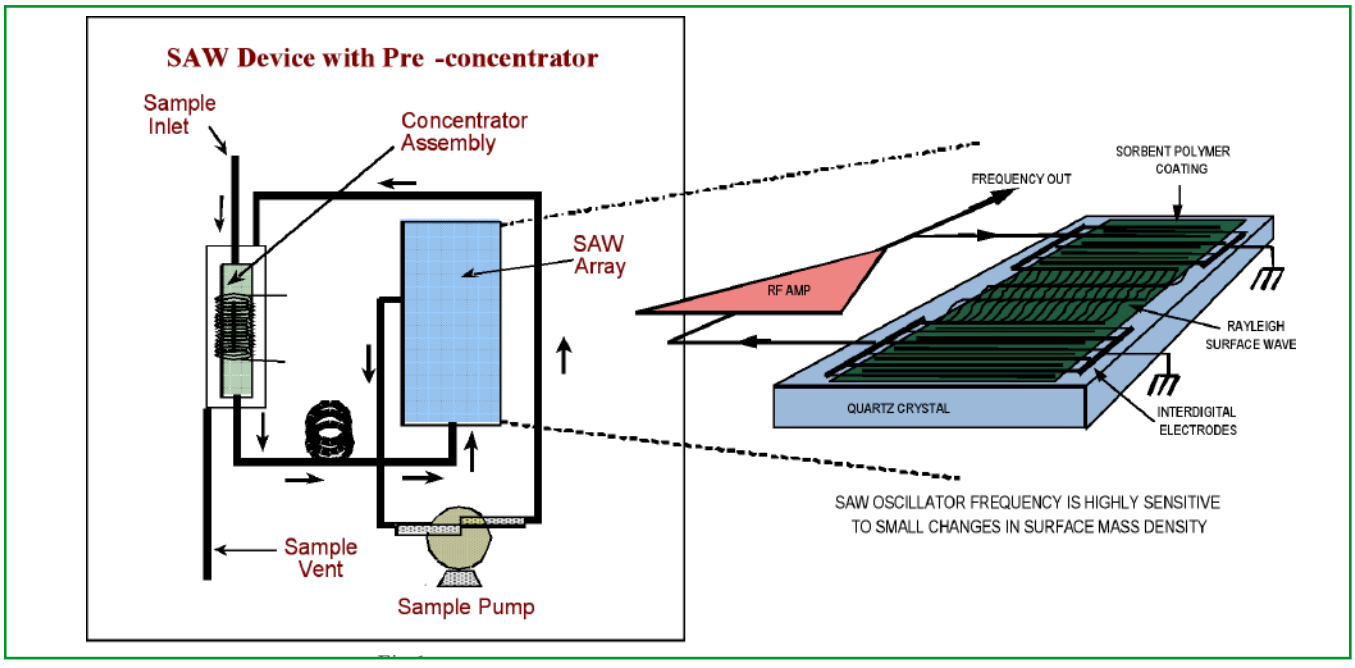

Figure 1.

Table 1.

Agent Classes	Characteristics	Exposure Symptoms	Agent Examples
Chemical Nerve Agents	Attack nervous system, can enter body through inhalation or skin	• Pinpoint pupils • Runny nose • Drooling • Coughing • Tightness in chest • Muscle twitching, jerking • Nausea, vomiting, diarrhea • Convulsions • Coma • Death	• Tabun (GA)--CAS #77-81-6: Odor: None or fruity • Sarin (GB)--CAS #107-44-8: Odor: None or fruity (used in Tokyo subway attack a few years ago) • Soman (GD)--CAS #96-64-0: Odor: None or camphor (mothballs) • VX--CAS #50782-69-9: Odor: None or sulfur
Chemical Blister Agents	Attack skin and can also be inhaled Are absorbed rapidly into skin	• Itching of eyes • Nausea, vomiting • Hoarseness or hacking cough • Initial redness of skin, followed by blisters • Skin effect varies with agent • Mustard gas (H): no immediate effect • Lewisite (L): immediate pain	• Mustard Gas (H)--CAS #505-60-2: Odor: Garlic • Lewisite (L)--CAS #541-23-3: Odor: Geraniums
Chemical Choking Agents	Attack respiratory tract	• Coughing, nausea, vomiting • Irritated eyes, nose, throat • Shortness of breath • Pulmonary edema • Frothy secretions	• Phosgene (CG)--CAS #75-44-5: Odor: Newly mown hay • Chloropicrin • Chlorine
Chemical Blood Agents	Attack circulatory system Have rapid onset	• Occur immediately • Loss of consciousness • Convulsions • Apnea • Headache	• Hydrogen Cyanide (AC)--CAS #74-90-8: Odor: Bitter almonds • Cyanogen Chloride (CK)--CAS #506-77-4: Odor: Bitter almonds

Blister agents are typically referred to by the abbreviation "H". "H" agent is commonly called mustard gas because synthesis impurities have an odor similar to that of garlic, horseradish, mustard or rotten onions. Mustard agents are classified as blistering agents primarily because exposure wounds resemble burns or blisters. There are two types of mustard gas, sulfur mustard and nitrogen mustard. The only difference between them is the replacement of the sulfur with a nitrogen molecule. The biological effects of mustard agent are tissue damage to the eyes, skin and lungs. Exposure to mustard agent can kill or severely incapacitate.

SAW Performance

SAW detector performance varies from manufacturer to manufacturer; therefore, the performance information below is only a guideline for expected performance and is not a specification.

Detection Limit

The sensitivity to nerve agents or blister agents varies from agent to agent; however, nerve agents can usually be detected below 1 mg/m^3 where as the detection limits for blister agents are approximately 1 to 2 mg/m^3.

Speed of Response

The time for the sensor to respond to mass changes in the selective polymer coating is typically less than a millisecond. However, in typical vapor-sensing applications it is more likely that the response time will be determined by the time required for the vapors to be transported to the polymer coating surface and for equilibrium to be established. Depending upon the way the gas is sampled, a true response time can range from 20 to 120 seconds.

Dynamic Range

The dynamic range of a typical SAW chemical sensor is 5 to 6 orders of magnitude, measuring from approximately 1 picogram to 1 microgram of vapor. This is dependent on the chemical vapor being measured.

Temperature

Performance of SAW devices can be affected by temperature variations. In extreme temperature conditions, the polymer coatings used in the SAW can physically change when the device is exposed to conditions outside of the operating temperature range. The coating will soften or harden if exposed to excess heat or cold, respectively. Once the coating has physically changed, the sensors ability to effectively detect the gas of interest is compromised.

Therefore, the device should be temperature controlled to obtain the best performance from the unit as well as ensuring that the device survives extreme ambient temperature swings.

Humidity

The different polymer coatings used in SAW devices have varying sensitivities to humidity. To dramatically reduce the effects of humidity on the performance of SAW instruments, a concentrator can be incorporated into the design to effectively allow moisture to pass through the system, while the vapors of concern are collected and later released with no moisture content.

Summary

Surface acoustic wave devices are an effective and reliable method for detection of very low levels of nerve and blister agents. Unlike other technologies, SAW devices are not typically subject to false alarms due to the presence of other compounds in the sample stream. Through proper design, the SAW detector can be used to effectively detect chemical warfare agents in a variety of environmental conditions.

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Corporate Headquarters:
P.O. Box 426, Pittsburgh
PA 15230 USA
e-mail info@MSAnet.com
www.MSAnet.com

U.S. Customer Service Center:
Phone 1-800-MSA-2222
Fax 1-800-967-0398

MSA Canada:
Phone 1-800-MSA-2222
Fax 905-238-4151

MSA Mexico:
Phone 52-55 2122-5770
Fax 52-55 359 4330

MSA International:
Phone (412) 967-3354
Fax (412) 967-3451

Offices and representatives worldwide
For more information: