

Integrated SAWs Using GaAs

A novel integrated microsensor being developed at Sandia National Laboratories will enable increased sensitivity for trace detection and identification of a variety of chemical species

Overview

The sensor combines surface acoustic wave (SAW) technology with microelectronics to produce a monolithic, compact, low-power integrated circuit microsensor. The sensor is fabricated entirely using processing technology available in Sandia's Center for Compound Semiconductor Science and Technology (CCSST).

Applications

The combination of low power, compact size, high sensitivity and robustness of integrated high-frequency SAW sensors makes them ideal candidates for applications requiring miniaturized and portable trace chemical detection capabilities. Such applications may require extended deployment in remote or inaccessible locations. The development of integrated SAW arrays will allow both detection and identification of a vast number of chemical species. In the future, we expect these devices to be employed for:

- Counterterrorism (including airport security)
- Nonproliferation (including chemical and biological weapons detection)
- Environmental monitoring
- *In-situ* industrial process monitoring and control

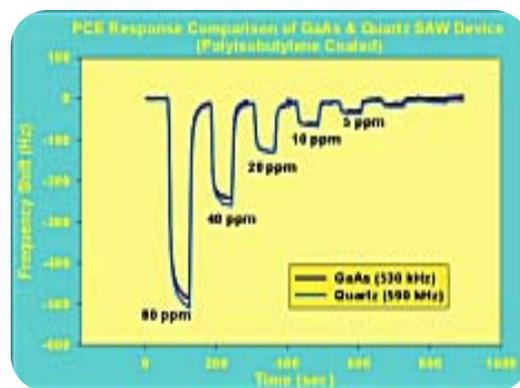


Figure 1. Detection of perchloroethylene (PCE), a volatile organic compound, using polymer coated SAW devices fabricated using both quartz and GaAs. Similar responses indicate that GaAs SAW sensors have a similar sensitivity to quartz-based devices.

Technical Approach Applications

SAW devices consist of a piezoelectric substrate, typically quartz, and two interdigitated transducers formed by photolithographic patterning of a thin metal layer. Application of an alternating voltage to the input transducer generates an alternating strain field that launches a surface acoustic wave that travels along the substrate surface before being converted back into an electrical signal by the output transducer. The velocity and attenuation of the propagating wave are very sensitive to properties, such as mass and viscoelasticity, of thin films formed on the device surface.

Quartz, the typical substrate for SAW sensors, is not a semiconductor while Si, the typical semiconductor used for microelectronics, is not piezoelectric and requires piezoelectric film deposition to enable SAW excitation. This makes Gallium Arsenide (GaAs) a unique material for use in integrated SAW microsensor applications. The piezoelectric properties of GaAs, which are similar to quartz, allow SAW devices to be fabricated directly on a GaAs substrate eliminating the need for deposited piezoelectric thin films. The data in Figure 1 show that the sensitivity of GaAs SAW sensors is comparable to quartz SAW sensors. In addition, GaAs is a well-developed semiconductor device material for fabrication of integrated high-frequency RF microelectronics.

The integrated GaAs SAW sensor is shown in Figure 2. It consists of a 470 MHz GaAs SAW device along with a multistage amplifier, forming a monolithic RF oscillator circuit. Each amplifier circuit contains 4 gain stages and an impedance matching output stage encompassing 32 transistors. The transistors are fabricated using a standard 0.8 micron gate length metal-semiconductor field-effect transistor (MESFET) process developed in the CCSST at Sandia. Currently, up to 5 of these devices can be fabricated on chip areas of 5 mm x 5 mm.

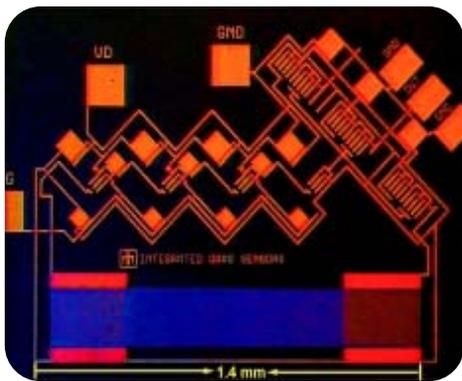


Figure 2. Picture of an integrated 470 MHz GaAs SAW sensor with associated oscillator circuitry for operating the SAW device at its center frequency and providing a frequency output that is sensitive to changes in SAW velocity.

Monolithic integration of acoustic sensors and supporting microelectronics leads to a number of advantages including reduced power consumption, reduced size, simplicity of packaging, and more economical device fabrication. By removing the need for high frequency interconnections, integration is helping us to move to higher frequency devices. As shown in Figure 3, increasing frequency provides enhanced sensitivity and smaller device size. The integrated SAW sensor is compatible with current state of the art quartz SAW sensor coating technology.

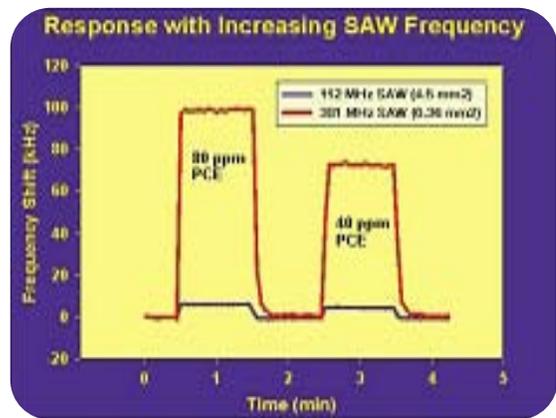


Figure 3. Response of identically coated SAW devices upon exposure to two concentrations of perchloroethylene (PCE) vapors. The higher frequency device gives a much larger response and is more than an order of magnitude smaller.

Future designs of these devices are expected to include:

- Different acoustic modes (flexural plate wave devices, thin film resonators)
- Compact multi-SAW sensor arrays
- Temperature compensation
- Data analysis microelectronics

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