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Comprehensive Threat Detection Modules

Chemical - Explosive - Bio Pathogen

NevadaNano Core Technology

At the core of the NevadaNano's sensor modules is our Molecular Analysis System (MAS) for identifying vapor molecules. It consists of a Preconcentrator module in series with our SSA™ (microcantilever-based Self-Sensing Array™ device). Vapor samples to be analyzed first pass through the Preconcentrator module where they are collected, pre-concentrated, and then separated for sequential introduction to the SSA for analysis. The separation function is similar to that performed by a Gas Chromatograph column and assists with accurate identification of the molecules present. The Preconcentrator technology (discussed later) was developed, tested and proven at Pacific Northwest National Labs and has been licensed exclusively by NevadaNano. After release from the Preconcentrator, the sample proceeds to the SSA for complete analysis. NevadaNano operates with the protection of 10 issued patents on its core technology with additional applications pending.

Self-Sensing Arrays (Microcantilever Sensors): Background

The Self-Sensing Array consists of an array of microcantilevers. A microcantilever is a diving-board-shaped beam of small dimensions, typically in the micrometer range, conventionally made of silicon or silicon nitride. These simple structures were originally used in measuring small forces for atomic force microscopes (AFM),¹ but have since lent themselves well to numerous chemical^{2,3} and biological⁴ sensing applications. Microcantilever-based detection has also been demonstrated specifically for sensing vapor,⁵ ultraviolet radiation,⁶ magnetic susceptibility,⁷ and low concentrations of plastic explosives (PETN and RDX) in air.⁸ Microcantilevers show further promise in early demonstrations for use as environmental and industrial health monitors, explosives sensors for landmine and terrorist threat detection, and biological sensors. They have found applications in sensors due to the exquisite sensitivity to mass changes (sub-nanogram-level detection,⁹ femtogram detection,¹⁰ attogram detection,¹¹ and even zeptogram detection,¹² which is 10^{-21} grams). NevadaNano has developed the ability to make inexpensive Self-Sensing Arrays to provide hundreds of orthogonal molecular measurements on single chip.*

* Orthogonal measurements are independent, complementary measurements which increase the ability of a sensor to correctly identify a particular vapor. Orthogonal measurements are critical for providing accurate identification of a sample. An orthogonal measurement is the quantification of a property unrelated to other measurements performed. The ability to measure numerous properties of a sample increases the probability of accurate identification since many different samples have some properties in common but none have all properties in common.

One of the most common ways to use a microcantilever as a sensor is to monitor its resonance frequency (i.e. the frequency at which the free end of the beam oscillates up and down). The beam can be sensitized with a chemical coating that absorbs the vapors given off by explosives, hazardous chemicals or even living things. As vapors absorb into the coating, the beam gets heavier, which reduces the resonance frequency. By measuring the reduction in the frequency the amount of adsorbed mass can be measured.

Historically, three problems have impeded the use of microcantilever sensors outside of the laboratory environment: how to actuate the cantilever, how to sense the movements of the cantilever, and how to purge analyte from the cantilever after a test is complete. NevadaNano has addressed all these issues and created a comprehensive, yet straightforward, self-actuating, self-sensing, and self-cleaning technology that will enable microcantilevers to fulfill their promise. The availability of a superb mass sensor in a microchip format provides many of the same benefits that silicon microchips have enjoyed—compactness, economies of scale, low cost, and high reliability.

Self-Sensing Array™ Technology: NevadaNano's Approach to Microcantilevers

Since microcantilevers are fabricated on silicon wafers, they can easily be configured into arrays, wherein each cantilever has its own resonance frequency and its own coating, and the response of the entire array to a given vapor input forms a pattern, like a fingerprint, which can be used to identify that vapor.

NevadaNano's core technology, which we call the Self-Sensing Array (SSA), features numerous microcantilever sensors configured electrically in parallel so that the electrical input and output of the array—just two leads—are the only two contacts needed to address the array for frequency driving and sensing, using a single circuit. Differences in fabricated length between cantilevers in the array allow each cantilever to have a distinct resonance frequency for use in a frequency-sweep method. Integrated piezoelectric sensing elements^{13,14,15,16} on the cantilevers eliminate the need for bulky, power-hungry, external optics and external actuators utilized by other cantilever-based approaches, reducing the sensing power requirements by more than four orders of magnitude versus other common sensing methods (lasers and piezoresistors).

The SSA provides more useful and reliable information due to the multiplicity of individual cantilever responses and the ability to selectively coat cantilevers with different adsorptive coatings.^{17,18,19} These coatings are selected so as to provide as many orthogonal measurements as possible. Each coating used for an orthogonal measurement has a chemical affinity for a different class of chemicals depending on fundamental interactions between the vapor and the coating (van der Waals interactions, polarity, Lewis acidity, etc.). By using an array of semi-selective polymer coatings and observing the unique pattern of sensor responses corresponding to a particular chemical vapor, the ability to identify a wide range of chemicals can be greatly enhanced.²⁰

While it is possible (and in some cases desirable) to coat a single cantilever with a specific coating to sense one particular analyte, the use of semi-selective, orthogonal coatings provides a much more universal approach. With a relatively small number of cantilevers and a different, carefully chosen coating on each one, in conjunction with our Artificial Neural Network for analysis, a single SSA is capable of sensing hundreds of analytes.

In addition to the use of coatings for identifying chemicals, the cantilevers also have built-in resistive heaters and temperature sensors, and the piezoelectric layer can be used as an

impedance sensor. In this way, the simple beam becomes a tiny laboratory, capable of measuring numerous chemical, electrical, and physical properties of adsorbed molecules at a variety of temperatures (see Figure 3). This unique technology enables us to make capacitive,²¹ resistive,²² calorimetric,²³ and thermogravimetric²⁴ measurements on our array of coated cantilevers. These additional measurements improve the accuracy of the chemical identification since many additional physical properties of the vapor can be quantified.

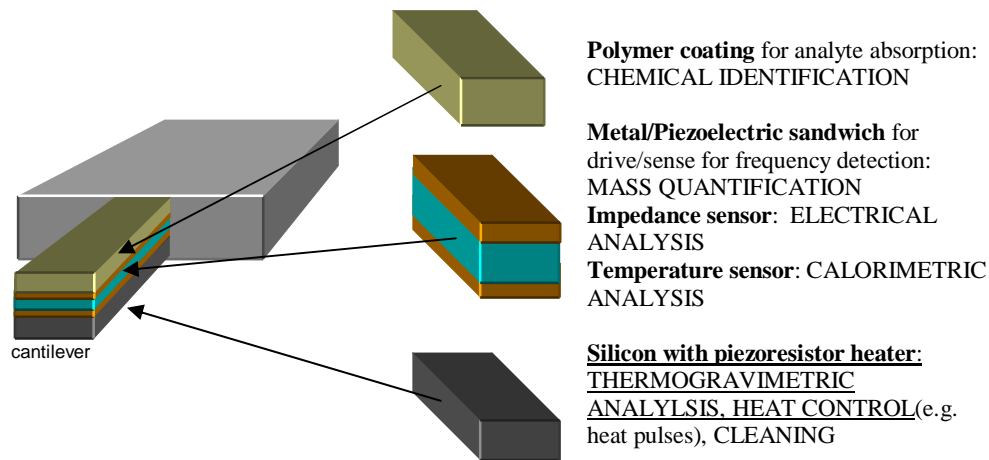


Figure 3: NevadaNano Self-Sensing Array™ Technology enables multiple, localized physical measurements to be made on the cantilever for enhanced selectivity. The piezoresistor heater can also be used to clean the sensor.

Once built, this multifunctional sensor is packaged in a flow-through chamber to allow vapors to pass through the sensing elements in the array. The package plugs into a socket in the sensor board, as shown in Figure 4.

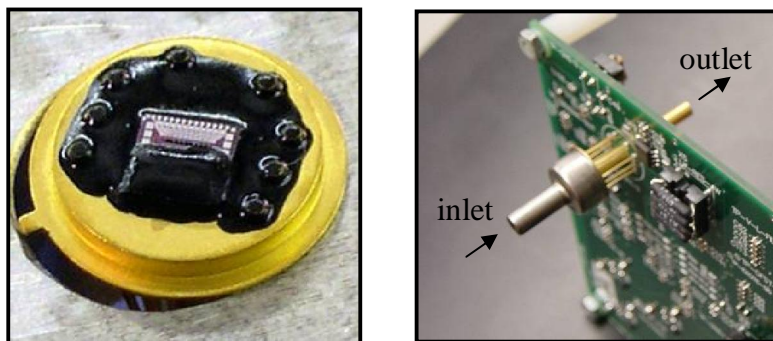


Figure 4: A close-up view of the sensor array mounted on the package is shown on the left. The sensor is shown mounted into the board as shown on the right.

Sample Collection, Concentration, and Separation

In order to maximize sensitivity and improve the chemical identification capability of our system, the first stage of our MAS (Molecular Analysis System) has been implemented using a preconcentrator technology licensed from the Pacific Northwest National Laboratory.²⁵ The preconcentrator consists of a tube packed with one or more absorbent

materials that trap vapors out of sampled air; once trapped, these vapors are subsequently separated for analysis by the sensor by ramping or stepping the temperature. Physical parameters of the trapped analyte vapors—such as vapor pressure and boiling point—affect the temperature (and therefore the time) at which each vapor will elute and be carried downstream to the sensor. Such separation enables even higher accuracy of chemical identification.

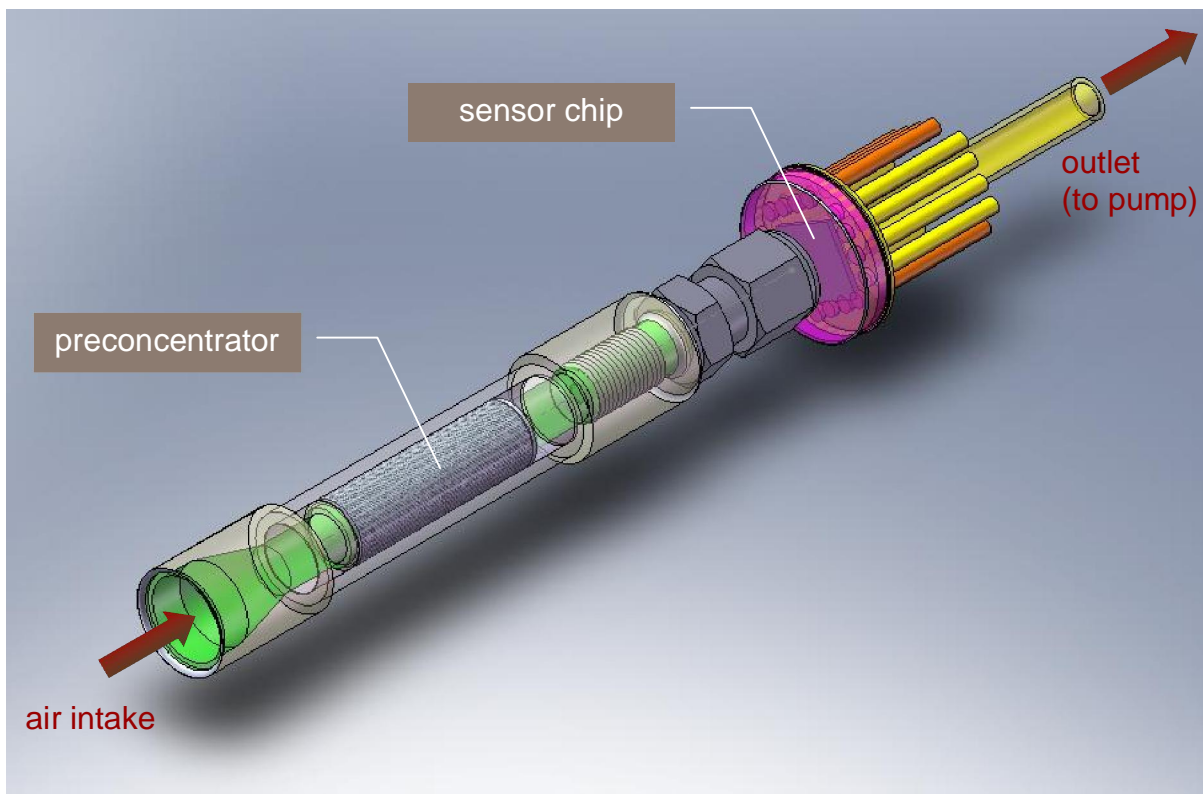


Figure 5: MAS core components—Preconcentrator and SSA sensor chip.

More Orthogonal Data Channels

The SSA provides more useful and reliable information due to the multiplicity of individual cantilever responses and the ability to selectively coat cantilevers with different adsorptive coatings, providing more orthogonal measurements—that is, independent, complementary measurements which increase the ability of a sensor to correctly identify a particular vapor. In addition to the use of varied coatings, the cantilevers also have built-in resistive heaters and temperature sensors. Also, the piezoelectric layer can be used as an impedance sensor. Given these capabilities, an array of simple beams becomes a tiny laboratory, capable of making capacitive, resistive, calorimetric, and thermogravimetric measurements. Each additional type of measurement adds a new perspective to the ability to classify a particular analyte.

Intellectual Property

NevadaNano has assembled a substantial portfolio of Intellectual Property pertaining to sensor elements, sensor arrays, sensing methods, coatings and coating application methods,

sample collection and processing, as well as software and signal processing. For more detailed information on our technology, please [contact us](#).

Conclusion

NevadaNano's SSA and MAS technology offers excellent sensitivity and selectivity for chemical, explosive, and bio pathogen sensing for molecules carried by air. Over the last four years and three DOD contracts, we have developed our unique SSA technology based on a proprietary, low-power microcantilever (MEMS) platform that enables sensing of hundreds of threats using a single, low-cost device that is small in size. Our SSA technology is inherently self-cleaning and self-calibrating. These characteristics enable our sensor modules to operate unattended for extended periods of time and be deployed in multiples over wide areas providing, for the first time, a truly ubiquitous threat sensing capability.

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